A decision enhancement studio for water asset management

Katumba, Proscovia

A DECISION ENHANCEMENT STUDIO FOR WATER ASSET MANAGEMENT

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Proscovia M. Katumba
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Promotores
Prof.dr. H.G. Sol
Prof.dr. J.T. Lubega

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The cost of discipleship is found in asset management and each of us will be held accountable by the Lord of Sabaoth. (Derived from Matthew 25:14-30)

PREFACE AND ACKNOWLEDGEMENTS

In this dissertation, we examined how decisions in water asset management can be enhanced. Within water and wastewater systems, an "asset" is part of a facility with an independent physical and functional identity and age, for example, a pump, a motor, a sedimentation tank, or a main. The renewal and replacement of assets that make up the water infrastructure is a constant task and to efficiently manage this important part of a utility's business, utilities have turned to asset management. Asset management has gained recognition across the world and across all infrastructure heavy sectors for its effectiveness in maximizing the value of capital as well as operations and maintenance expenditures.

Through exploration and literature, I identified decisions that matter in water asset management, which enabled me to come up with requirements that support a decision-making environment. I have provided asset management guidelines and tools in a studio environment to support decision-makers in water asset management. To find improvements that can inform decision processes inherent in water asset management, I focus on prolonging asset life and supporting decisions to rehabilitate, repair and replace assets at various managerial levels through efficient and focused strategy formulation, tactical and operations maintenance. I have developed repeatable processes to provide structure to decisions in water asset management.

Attaining a PhD has been a unique and gratifying effort. I am indebted to all persons who have supported me in this journey. First, my appreciation goes to my promoter, prof. dr. Henk G. Sol, for his invaluable support academically, morally and logistically. In various encounters, he kept me afloat with his rational and wise guidance; he connected me to his extensive network of experts. He educated me on how to use the inductive-hypothetical research strategy and gave me an understanding of design science research, where I have greatly benefited. Special mention goes to Jacqueline Sol for her generosity and hospitality; I am truly grateful.

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Proscovia M. Katumba

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER 1
WATER ASSET MANAGEMENT IN TRANSITIONAL COUNTRIES

World over, managing critical water and sewer assets is becoming increasingly difficult. The challenges of ageing infrastructure, limited funding and regulatory compliance dare sector managers to do more with less while focusing on the future. This research looks into these managerial challenges and explores a new approach that can be used to improve management of assets. The study aims at facilitating complex asset management decisions by providing architecture of services. First, I discuss challenges facing water asset management. Section 1.2 addresses the focal point of the study, which is decision enhancement. Section 1.3 presents the research problem while section 1.4 specifies the research problem and the research objective. The research approach is presented in section 1.5 that covers the research philosophy, strategy, and instruments. Section 1.6 concludes the chapter by presenting the thesis outline.

1.1 Challenges Facing Water Asset Management

Globally, 1.1 billion people lack access to improved water supply, and 2.6 billion are without improved sanitation (Ardakanian & Martin-Bordes, 2007). In urban areas of transitional countries, there are two major systems: the water supply and the wastewater (or sewerage) systems. The dynamics of rapidly changing situations in urban areas presents challenges to the provision of water, namely the increasing number of people without direct access to safe drinking water and very few households being provided with water borne sanitation systems (Peter-Varbanets et al., 2009). In addition, the water systems of urban areas in transitional countries often break down causing disruption of service to the public. Diseases associated with water affect the poor in unequalled ways, and this burden of ill-health maintains the vicious cycle of poverty and sickness (Ardakanian & Martin-Bordes, 2007).

Around the world, hundreds of billions of dollars are spent in managing assets. However, along with monetary significance, the rising importance of asset management is being fuelled by other factors, such as the general ageing of assets; changing stakeholder and service level requirements; augmented emphasis on public health and safety; and the

increasing stringent requirements set by regulating bodies (IAM, 2004; Lutchman 2006). To deal with these issues, an assessment of the needs of sector managers, other stakeholders and existing circumstances can disclose opportunities for proposing services to improve sector managers' decisions for asset management.

Improved water asset management can be a catalyst for economic growth, where major water infrastructure investments can transform development prospects (FAO, 2007). Water provides critical inputs for many productive activities and creates opportunities for local entrepreneurs in supplying technologies, constructing facilities and providing services. Where major infrastructure investment is accompanied by incentives that trigger private enterprise and livelihood opportunities, then water investments can play a key role in poverty reduction (Ardakanian & Martin-Bordes, 2007). Managing and investing in water and sanitation infrastructure constitutes an urgent and major challenge (MDG, 2013).

Asset management covers a wide area and has roots in many disciplines. The application of asset management principles in the global water industry is of particular interest now due to pressures from government, regulators, shareholders and consumer groups to provide them with cost-effective and sustainable water services to the customers and to the environment (Bhagwan, 2009).

Water quality and safety

When the water quality of an aquifer has been degraded, the aquifer may no longer be considered a safe drinking water source without treatment. However, groundwater designated for use may still be utilized even if it is contaminated (Honeycutt et al., 2012). Threats to ground water quality can be a source of pollution (Viers et al., 2012). Pollutants occur over a wide area and may include leaking underground septic systems and discharge from wastewater treatment plants to percolation basins (Honeycutt et al., 2012). According to the MDG (2013) targets, there are persistent concerns about the quality and safety of many improved drinking water sources. Most people around the world need piped drinking water in their premises. Yet, 38 per cent of the 6.2 billion people globally using unimproved drinking water do not enjoy the convenience and the

associated health and economic benefits of piped drinking water in their homes. Instead, they spend valuable time and energy queuing up at public water points and carrying heavy loads of water home (MDG, 2013).

Contamination of water sources

Water pollution is a major world problem, which requires constant evaluation and introduction of mitigation measures at all levels (internationally and down to individual aquifers and wells). There are high costs associated with wastewater treatment and water quality management programmes for large water users to treat their waste in-house rather than discharging it untreated into a water resource (Lawless, 2010). In most countries, water systems receive little monitoring or regulatory attention, and are typically vulnerable to ambient pollution (Honeycutt et al., 2012). Eutrophication of lakes and reservoirs is a serious issue due to the continuous loading of organic matter, phosphorus and nitrogen into these water bodies (Yang et al., 2008).

Scarcity of water sources

By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under conditions of water stress (UN, 2007). The situation will be exacerbated as rapidly growing urban areas will put heavy pressure on local water resources. According to FAO (2007), there are four main drivers of increasing water scarcity during the coming decades. First, there is the inexorable growth in population. Second, the world is expected to become increasingly urbanised, focusing the demand for water within a concentrated population. For example, Asian cities are expected to grow by 1 billion people in the next 20 years. Third, the amount of domestic water that each person uses, per-capita consumption, is expected to rise as the world becomes more developed. Fourth, while these factors will increase the demand for water, freshwater resources will change because of climate change. The magnitude of this change will vary from one region to another; some regions will probably see an increase in the variability of precipitations, leading to more frequent periods of drought (UN, 2007).

Climate Change

Water is the principal medium through which climate change exhibits its environmental, economic and social impacts. Water-related disasters such as droughts, floods and major storms undermine development and destroy infrastructure (IPCC, 2001a). Today climate adaptation and climate resilience have become the buzzwords in the corridors of power. According to analyses (the Organization for Economic Co-operation and Development [OECD], 2005), an estimated 40 per cent of development investments in water assets are currently at risk. These analyses indicate that while many development efforts contribute to reducing vulnerability to climate variability and change, climate risks are seldom explicitly factored into development projects and programmes. However, The World Bank estimates of the additional costs to climate-proof new investments range from $9 to $14 billion a year (OECD, 2005).

Ageing Infrastructure

Water utilities face great challenges as ageing infrastructure require significant investments in rehabilitation, replacement, and expansion (Hendrickson & Horvath, 2014). Reducing environmental impact is essential for utility managers and policy makers. Utility leaders are grappling with significantly high budgets required to replace ageing water infrastructure to comply with existing and future water regulations (Hoene & Pagano, 2010). However, with water related services twice as capital-intensive as electricity and three times as capital intensive as gas, many communities simply cannot afford to upgrade their ageing systems (Ashley & Cashman, 2006). As utility budget shortfalls increase, one way for them to cover budget deficits has been to engage in workforce reductions, such as laying off staff, furloughs, hiring freezes and delaying or cancelling capital infrastructure projects (Hoene, 2009).

Maintenance of existing infrastructure

There has been under-investment in the maintenance and refurbishment of water infrastructure, which is evident in the number of service delivery failures across South Africa (Lawless, 2010). The Blue Drop system implemented by the Department of Water Affairs in 2008, demonstrates clearly the extent of the maintenance challenges in South

Africa (DWA, 2009). The high volume of technical water losses due to pipe bursts or leakages, also results in substantial revenue losses for municipalities – revenue that could have been used for further maintenance (Lawless, 2010). In most transitional country cases, Non-Revenue Water (NRW) target setting is simplistic. There is no agreement regarding what criteria should be used to determine a water loss or NRW target (Gonzalez-Gomez et al., 2011) because local factors explain differences in leakage levels within cities (Skipworth et al., 1999; Lambert, 2000). Generally, lower water loss targets, 10 per cent, are recommended for developed nations, and less than 23 per cent for transitional countries (Tynan & Kingdom, 2002). NRW data indicate that there is much room for improvement in water asset management in cities. It also suggests a lack of motivation to solve the problem in the short term mainly due to lack of incentives for management units, defence of private interests due to corruption, lack of awareness of the users (i.e. citizens) of the water service and lack of the political will (Gonzalez-Gomez et al., 2011).

Meeting stricter regulations

Intrinsic inefficiency of traditional public sector provision of goods and services has inspired an increasingly commercial environment, tighter financial controls, increased competition, and in some cases, proposals to transfer to the private sector through privatization (Ogden, 1995). Water corporations are subject to 'yardstick' competition under new regulatory frameworks and comparative judgments by financial markets (Mugisha et al., 2007).

Growing demand for a finite resource

Because of pressure from rising populations, intensive agriculture and industrialization, water has become a scarce resource (FAO, 1990). The World Bank estimates that demand for water will exceed supply by 40 per cent by 2030 (World Economic Forum, 2012). Ardakanian & Martin-Bordes (2007) suggest that 1.8 billion people live in regions already classified as water scarce. Many countries are falling behind in their progress towards attaining the specific MDG on water and sanitation (MDG, 2013).

A DECISION ENHANCEMENT STUDIO FOR WATER ASSET MANAGEMENT

Water Management Challenges

Water governance is more than national level water legislation and institutions, though these are important components (UNDP, 2004). Amongst the managerial aspects identified are: missing focus and a lack of top management's full commitment (Kingdom et al., 2006); and lack of sound management and management inefficiencies in form of delays in responding to leaks and bursts (GIZ, 2010). Others include commercial losses due to erroneous meter readings, lack of customer care services like use of call centres and existence of many illegal users (Mugisha et al., 2007).

Decision challenges faced by water systems

According to the Environmental Protection Agency (2008), utilities face challenges including determining the optimal time to repair and replace ageing assets; responding to emergencies as a result of asset failures; detecting incipient failures long before their occurrence (Veldman et al., 2011); and protecting assets (National Water Commission, 2012) in the quest for improving water asset management.

Inadequate funding

Access to safe drinking water and sanitation services is affected by huge investment requirements (Hildering, 2004). Rehabilitation and improvement of water services requires exorbitant funds. The UN Task Force on Water and Sanitation argue:

> National governments including planning and finance ministries and their supporting agencies must be conviced of the importance of achieveing the MDGs in water supply and sanitation. They need to recognize that water and sanitation are essential for the success of all development (Lenton & Wright, 2004).

In many of the transitional countries where service levels are inadequate, there is gross misuse of financial resources through over-expenditure. In addition, revenue generation practices are inadequate, as collections are low and service quality is poor (Mugisha et al., 2007).

Negative attitude towards maintenance

Good governance and cultural habits influence the dynamics and time frame of modernising water management in a country (GIZ & VAG, 2011). A culture, philosophy and new attitudes toward maintenance (Chowdhury, 1995) can be inculcated as understanding and awareness grow in line with preservation of assets for sustained performance. Attitudes towards the value of routine maintenance activities are evolving with the realization that maintenance is necessary. The changes under way involve business attitudes and basic cultural values of the organization. Within the maintenance community, promote a culture of continuous improvement with a view that technology, business practices, and management techniques should change continually for the benefit of customers (Skinner et al., 2006). More so, a proactive and innovative attitude to asset management should be fostered, instead of reactive approach; should drive fact-based reviews of the asset base, suggest innovations and dynamically adjust its processes and organization to new issues (World Economic Forum, 2014). Nonetheless, the investment in maintenance is not in tandem with the investment in new infrastructure assets, that is, not as much effort and budget is devoted to maintenance as is to acquisition of new infrastructure assets. This is a major maintenance related problem for developing countries (World Economic Forum, 2014). Additionally, utilities usually underestimate the maintenance effort and funds required. This has a direct negative impact on the operational expenses (OPEX) and Earnings before interest, taxes, depreciation, and amortization (EBITDA) result of the company, rather than depreciation of an asset implemented via asset investments. In the end, there is the run-to-fail maintenance strategy, which might not always be appropriate, that is, “don’t fix it if it’s not broken attitude”. It is also usual to find that organisations don’t always have the required capability or capacity internally to maintain its infrastructure internally. Increasingly, infrastructure operators need to “do more with less” (Brown & Swersky, 2013). Furthermore, the resistance and negative attitude during implementation stages is mostly caused by lack of knowledge and consultation between management and employees at lower levels (Miya & Grobbelaar, 2015). Therefore, communication during maintenance should be improved in order to promote positive attitudes to maintenance as well as increase effort in and budget for water asset management.

Income gaps

Income inequality is on the rise both within and across countries, developed and transitional alike and environmental problems are exacerbated by income inequality especially for clean water and sanitation (UN, 2013). Disparities exist between the rich and poor and are much greater in sanitation than water, water coverage is lowest in Africa and Oceania and water unmet needs are highest in sub-Saharan Africa (UNICEF, 2004). The poor are less likely to have water and sanitation access. Once inequality and disparities reach extreme levels, they can lead to political instability and in some cases violence and conflict; vandalism and insider sabotage are significant contributions to vulnerabilities towards critical assets (Bhagwan, 2009).

Inadequate sewage treatment systems

Most cities and towns in transitional countries do not have sewage treatment plants; therefore, the consequences of continued discharge of raw sewage into the environment are serious and they cause irreversible damage to the aquatic environment as well as posing health risks from exposure to pathogens entering the environment (Okoh et al., 2010). The problem of inadequate sewage treatment is particularly important, given the huge volume of sewage that must be treated to prevent waterborne diseases (Johnson, 2006). Inadequate sewage treatment is one of the chief causes of waterborne diseases, which has acute impacts on infant mortality (Goff, 2010). In Africa, the great majority of communities have no sewage treatment capability, and 60 per cent of households lack toilets (Hogan, 2011).http://www.eoearth.org/view/article/155987/ - endnote_5 In Kenya, for example, approximately 17 per cent of the communities have some form of sewage treatment, while in Sudan the number is quite low (Hogan, 2011).

Operational inefficiencies

Inefficiencies are divided between distribution losses and revenue under-collection. Average distribution losses stand at 35 per cent, far above the world normal loss of 20 per cent, with all countries affected to some degree (Wyatt, 2010). The World Bank (2006) has estimated that, on average, apparent losses - in particular theft through illegal connections - account for about 40% of Non- Revenue Water for transitional countries.

With the average collection ratios at 90 per cent, it falls short of best practices. In the worst cases, such as the Democratic Republic of Congo, Ghana, and Zambia, the afore-mentioned inefficiencies can create an economic burden of 0.7 to 1.0 per cent of GDP (see figure 1-1).

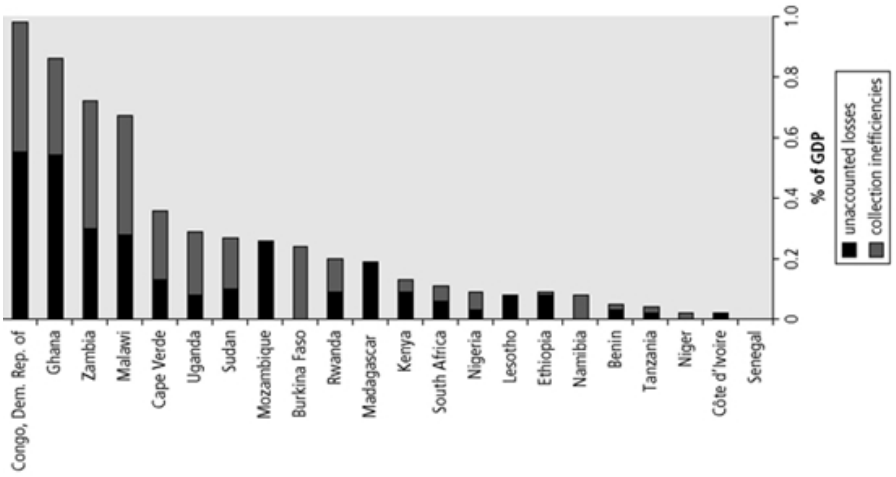

Figure 1-1: The Economic Burden of Water Utility Inefficiencies on GDP (Briceho-Garmendia, Smits, and Foster, 2008)

In South Africa, non-revenue water is estimated to be around 35 per cent of the water supplied (Lawless, 2010). Although South Africa's non-revenue water is lower than that of other developing countries, much scope still exists for improving operating efficiency. The primary concern is with water losses due to poor maintenance, inaccurate or incomplete billing and water theft (Lawless, 2010). In other words, NRW is primarily caused by the lack of or poor infrastructure asset maintenance (maintenance management), which is one of the key performance areas of infrastructure asset management (Mugisha & Berg, 2008). Thus, this research on water asset management focuses on maintenance management under infrastructure asset management.

Information management

According to GAO (2004), integrating information for decision making across departments is the challenge that utilities are grappling with. Water utilities also reported that, the shorter-term focus of their governing bodies could hamper long-term planning

efforts. Water industry officials raised concerns about the implications of mandating asset management, citing challenges in defining an adequate asset management plan and in the ability of governments to oversee and enforce compliance (GAO, 2004). Companies that sustain success in asset management develop decision disciplines that are an integral part of their organizational culture. Some corporations practicing asset management engage in business process modelling initiatives that are generally carried out in an ad-hoc manner or non-systematic manner (Frolov et al., 2010) leading to poor asset management decisions. There is the need for information management because "in post-capitalism, power comes from transmitting information to make it productive, not from hiding it" Drucker (1995).

Information and Communication Technology

The unprecedented advancements experienced in the field of information systems has resulted in improved performance and increasingly sophisticated information platforms. Information and Communication Technology (ICT) can often be used in a number of low-cost but highly effective ways to educate communities on water, sanitation and hygiene (WHO, 2008). While hardware is exhibiting more compatibility and functionality, software is showing outstanding interface and reliability capabilities that enable decision-makers to process the dramatically growing volume of information available to them (Gasmelseid, 2011). ICT is used for administrative support, meetings, analysis, information, communication and presentation support, but not for direct enhancement of critical decision processes (Keen & Sol, 2008).

1.2 Decision Enhancement

Decision Enhancement (DE) of Keen and Sol (2008) originates from the decision support systems research field (Gorry & Scott Morton, 1971; Keen & Scott Morton, 1978; Nunamaker et al., 1996; Sprague, 1980). The field came out from decision support systems and was expanded to executive information systems, knowledge management systems, data warehousing and business intelligence (Arnott & Pervan, 2005). Keen and Sol (2008) instituted decision enhancement following a studio-based approach as an improvement in the decision support systems research field focusing on ill-structured and

complex decisions termed as decisions that matter. These decisions are urgent, consequential, non-avoidable, non-reversible, and uncertain or wicked with no right answer (Keen & Sol, 2008).

The concept of a "studio" is introduced in decision enhancement is defined as a facilitative interactive environment for decision enhancement to enable executives to rehearse the future (Keen and Sol, 2008). As Keen & Sol (2008) affirm, "DE provides services to guide a journey where executives, their advisors, change management, specialists, experts in multi-disciplinary fields and technology developers can come together to make a substantive new impact on effective decision-making in any organization." They envision a decision support studio as facilitative simulation environments designed to enable executives to rehearse the future. As they explain: "Rehearsing the future rests on vision, envisioning shared images, collaboration and communication among people scattered across the organization and more and more outside relationships". Studios are not simulation environments in the traditional sense of the word, they "embed system tools in executives' decision processes" (Keen & Sol, 2008).

According to Keen & Sol (2008) studio-based decision support encompasses:

i). *People*: the actors representing a whole scope of disciplinary and interdisciplinary dimensions in the context of the problem to be solved;

ii). *Process:* a process founded in the method of inquiry, guiding search towards a solution; and

iii). *Technology*: suites of interrelated information and communication services, simulation instruments, analytic methods and visualization interfaces.

A suite of software services is the foundation for meshing technology and process (Keen & Sol, 2008). The suite consists of domain specific information and communication services, which form building blocks and support recipes for repeatable processes just as a surgeon uses a specific toolbox to operate on a specific patient. Moreover, that the choice of instruments will depend on the decision context, the roles of the involved actors, and possibly, the personal preferences of the managers involved.

Therefore, we have based this research on the proposition that the studio can be used as an enabling technology to improve the effectiveness of decisions in water asset management. Therefore, our research problem is formulated to concur with Ahuja's (2009) observation that a problem cannot be formulated in a vacuum.

1.3 Research Problem

One of the major issues affecting small to medium water and sanitation utilities in transitional countries is ineffective decision-making in water infrastructure asset management, particularly maintenance management. There is growing evidence suggesting that the integrity of drinking water and wastewater infrastructure is at risk without collaborative effort to improve the management of key assets such as pipelines, treatment plants other facilities and a significant investment in maintaining, rehabilitating, and replacing these assets (Bhagwan, 2009). Moreover, poor infrastructure asset management has led to many inherent problems such as leakages in the pipe network and ageing infrastructure. Mugisha and Berg (2008) explain that these issues have contributed to the high share of non-revenue water (NRW) at 40 per cent in Kampala. The NWSC report (2009) also relates the high share of NRW to the poor condition of the existing infrastructure. The hypotheses used for the calculations are conservative: most small to medium water and sanitation utilities in transitional countries have NRW that exceeds 50 per cent, and the true marginal cost of water will often exceed US $0.20/cubic meter (Kingdom et al., 2006). Thus, a low cost solution that addresses operational and tactical level decisions within infrastructure asset management (maintenance management) for the short to medium term period would be a step towards solving the NRW issue.

While this challenge is significant, decision enhancement (DE) studios through knowledge and tools have been observed to make a difference in several complex situations that comprise rural women, urban poor, and other vulnerable groups. There is a growing body of evidence that decision enhancement is effective in other complex domains such as business process management (Amiyo, 2012), starting a miner's enterprise (Ejiri, 2012), e-Government initiatives (Yonazi, 2010), mainport planning (Chin, 2007) and education (Bequette et al., 1999; Bequetter et al., 2001; Hundhausen,

2002). This research endeavours to develop an environment for collaboration among stakeholders to focus on enhancement of processes that influence the quality of decisions that really matter (Keen & Sol, 2008) in water infrastructure asset management for the short to medium term in small and medium water and sanitation utilities in transitional countries.

1.4 Research Objective

The objective of this study is to develop a decision enhancement studio that facilitates complex asset management decisions by providing services to enhance decision-making.

Stemming from Keen & Sol (2008), a *decision enhancement studio for water asset management* is postulated as an appropriate means to achieve the objective of this research. Decision enhancement seems to fit well within the complexity of decision-making amongst sector managers with multiple responsibilities. Furthermore, Keen & Sol (2008) state, "DE provides services to guide a journey where executives, their advisors, change management, specialists, experts in multi-disciplinary fields and technology developers can come together to make a substantive new impact on effective decision-making in any organization." Therefore, a proposed decision enhancement studio with suites and guidelines can be a useful tool for decision-making and used as an enabling technology to improve the effectiveness of decisions in water asset management.

1.5 Research Approach

The research approach highlights the philosophy, strategy, and instruments that were used to conduct the research (Galliers, 1992).

Research Philosophy

Research philosophy refers to the perspectives that researchers possess in the process of knowledge development (Creswell, 2003; Trochim et al., 2007), strategies of inquiry, and specific research methods (Creswell, 2003). The philosophical grounding of this research is founded on design science. The design science philosophy is effectuated with the inductive-hypothetic research strategy of Sol (1982) in order to create a studio for

decision enhancement for water asset management and to achieve scientific contribution as well as contributions to the society (relevance).

This information system research uses three major ways of thinking about research philosophy: epistemology, ontology and axiology. Accordingly, Flowers (2009) explains these philosophies as follows: ontology describes the nature of reality; epistemology explores the nature of knowledge; and axiology is the study of values. From a philosophical point of view, there are three epistemological choices available for design science research projects: positivism, interpretivism and pragmatism (Gonzalez & Sol, 2012).

Positivism assumes that "the truth is out there" and that it can be reached through the methods of science (Wynn, 2001). Positivist research can be identified by the presence of hypotheses, propositions, models, quantitative variables and statistic inference of "objective" data (Myers, 1999). Extreme positivism in information systems research sees technology as neutral; it believes in rational management, ignores power relations and conflict, sees organizations as individual closed entities and focuses on the business environment (Mitev, 2000).

Interpretivism assumes that one's background shapes their interpretation, and they "position themselves" in the research to acknowledge how their interpretation flows from their own personal cultural and historical experiences (Creswell, 2003). Therefore, the researcher's intent, then, is to make sense of (interpret) the meanings others have about the world. Rather than starting with a theory such as in positivism, inquirers, generates or inductively develops a theory or pattern of meaning (Creswell, 2003). Interpretivism argues that both the researcher and the human actors in the phenomenon under study interpret the situation (Nandhakumar & Jones, 1997).

Pragmatism stems from the understanding that our beliefs guide our desires and shape our actions (Gonzalez & Sol, 2012). In other words, pragmatism argues that the most important determinant of the research philosophy adopted is the research question and that one approach may be better than the other in answering particular questions.

Pragmatism is not just epistemological in scope, but it also holds a particular theory of knowledge and truth. Essentially, pragmatism places the weight of truth on the consequences of beliefs, where beliefs are progressively attained through the method of science (Peirce, 1992a). "Linking up our conception of these effects is the whole of our conception of the object" (Peirce, 1992b). This appears to fit the design science aim towards utility because truth is utility or "what works in practice" (March & Smith, 1995). Pragmatism correlates with the ontological position of critical realism seen as a re-establishment of "a realist view of being in the ontological domain whilst accepting the relativism of knowledge as socially and historically conditioned in the epistemological domain" (Mingers 2004).

Table 1-1 provides an overview of the three epistemological choices, namely positivism, interpretivism and pragmatism, which are available for design science research projects (Gonzalez & Sol, 2012).

Table 1-1: **Three epistemological choices for design science research projects (derived from Gonzalez and Sol, 2012)**

	Positivism	**Interpretivism**	**Pragmatism**
Definition	• Truth is out there (Wynn, 2001). • Single, uniform reality that researchers attempt to measure in a precise, objective, and neutral manner.	• Truth is interpreted. • Both the researcher and the human actors in the phenomenon under study interpret the situation (Nandhakumar & Jones, 1997).	• "Truth […] is what works • in practice" (March & • Smith, 1995). Beliefs guide our desires and shape our actions, thus, research philosophy adopted is determined by research questions (Gonzalez & Sol, 2012)
Researcher Involvement	• Researcher independent of what is being researched.	• Researcher is part of the research process	• Researcher is actively involved and satisfied by descriptions of 'local knowledge' (Valsiner, 2006). Researcher is an "active participant" in solving practical problems (Peffers et al, 2007).
Alternative Philosophy	• Direct Realism – What you see is what you get. What we experience	• Constructivism – inquirer and the phenomenon under inquiry are inseparable.	• Critical realism – experiences are sensations, the images of the things in the real world. • Critical researchers stress action research: create

	Positivism	Interpretivism	Pragmatism
	through our senses portrays the world accurately.		organizational change and study the process (Kizito 2009). Social reality is historically constituted and produced and reproduced by people (Myers, 1997).
Research Methods	• Quantitative	• Qualitative	• Pluralist /Mixed methods (Creswell, 2003). "Methodological options partly dependent on what are being achieved" (Baert 2004; Hirschheim 1992; Mingers 2004).
Research Choice	• Deductive hypothesis	• Inductive hypothesis	• Inductive hypothesis reasoning where artefacts are designed as prescriptive conceptual models that are to be validated (Gonzalez & Sol, 2012). Worth noting, is that the inductive-hypothetic approach, based on Singerian inquiring systems, is closely related to pragmatism (Gonzalez & Sol, 2012).
Sample size	• Study large samples in order to generalize conclusions	• Small samples with less need to generalize	• Small samples to support easy building and testing of models (Venable & Baskerville, 2012).

In this research, we follow the thought process based on pragmatism because of the ill-structured nature of the problem. The study is guided by the inductive-hypothetical reasoning where artefacts are designed as prescriptive conceptual models that are tested for one to understand their effects in the organizational context.

The *pluralist research methods* (quantitative and qualitative) are adopted from a neo-pragmatic analysis in which different methods depend on what one aims to achieve (Baert, 2004; Hirschheim, 1992; Mingers, 2004). Pluralist/mixed research methods have come of age. To include only quantitative and qualitative methods falls short of the major approaches being used today in the social and human sciences (Creswell, 2003). Pluralist/mixed research methods enable the researcher obtain richer and more reliable results (Mingers, 2001). Therefore, the subject matter of a science determines the techniques and instruments used by the researcher (Miles & Huberman, 1994). The

choice of a method to use is based on the research problem, personal experiences, and the audiences for whom one seeks to write (Creswell, 2003).

The author concurs with Myers (1997) that *critical researchers* assume that social reality is historically constituted and that it is produced and reproduced by people. Although people can consciously act to change their social and economic circumstances, critical researchers recognize that their ability to do so is constrained by various forms of social, cultural and political domination. The main task of critical research is regarded as that of social critique, whereby the restrictive and alienating conditions of the status quo are brought to light. Critical researchers emphasize action research (Myers, 1997).

Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework (Rapoport, 1970). The definition draws attention to the collaborative aspect of action research and possible ethical dilemmas that arise from its use. Clark (1972) emphasizes, that action research is concerned with enlarging the stock of knowledge of the social science community. This aspect of action research distinguishes it from applied social science, where the goal is to apply social scientific knowledge rather than adding on to the body of knowledge (Myers, 1997). Unlike other research methods, where the researcher seeks to study organizational phenomena instead of changing them, the action researcher attempts to simultaneously study the process and create organizational change (Kizito, 2009). Peffers et al., (2007) state that design science research comes from a history of design as component of engineering and computer science research, while action research originates from the concept of the researcher as an "active participant" who seeks to solve practical problems in the course of studying.

Research Strategy

After selecting the research approach and philosophy, the next step was to identify an appropriate research strategy for the problem domain. Therefore, the inductive-hypothetical cycle that utilizes the problem-solving process as a means for research was adopted. Problems in asset management of a water utility are complex and ill structured

because decisions lack a specific method for solutions. The organization of water asset management responsibilities has been characterized as "chaotic" (Steen & Pellenbarg, 2004; Smit, 2004), because tasks are shared among different authorities and in different ways. For example, the Water Boards operate in a complex arena of national, regional and local entities. In this regard, the author sought to obtain first-hand information, through practical experience in real-life organizational settings, on the means to overcome some of the challenges in water asset management.

Therefore, the inductive-hypothetical research strategy suited for ill-structured, consequential, complex, and uncertain decisions was chosen to address these concerns. Accordingly, a research strategy consists of a set of steps used to address a research problem. The inductive-hypothetical research cycle (Sol, 1982) can be characterized as an early instantiation of design science. The inductive-hypothetical cycle has various steps between the identification of problems and the formulation of solutions. These steps further conceptualize the problem situation. The inductive-hypothetical model cycle (Figure 1-2) consists of five steps: initiation, abstraction, theory formulation, implementation, and evaluation (Churchman, 1971; Sol, 1982).

As shown in Figure 1-2, the inductive-hypothetical cycle has five stages. The research problem initiation, involved identifying decisions that matter in water asset management leading to a descriptive empirical model. The second stage, abstraction, dealt with identifying issues in water asset management and requirements were derived giving a descriptive conceptual model. This stage focused on in-depth literature review and exploration. The third stage dealt with theory formulation whose output was a prescriptive conception (design). Design is essentially a search process to discover an effective solution to a problem (Hevner et al., 2004).

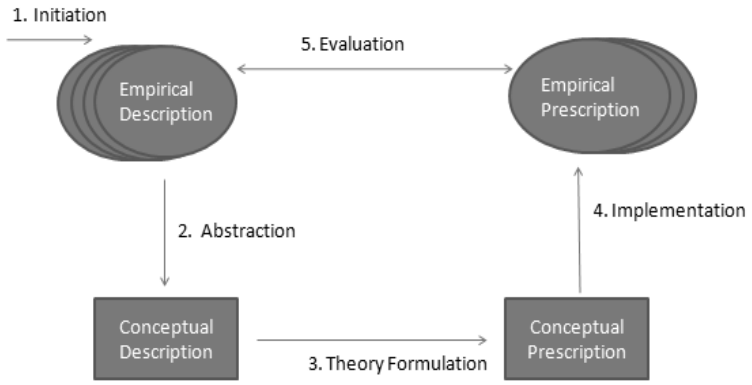

Figure 1-2: Inductive-hypothetical research strategy (Sol, 1982)

The fourth stage involved prototyping and implementation with an output of an empirical prescription, the solution was tested and evaluated at the fifth stage. These stages are further described below.

Initiation Stage

The problem domain was concerned with developing a decision enhancement studio that facilitates complex asset management decisions by providing services to support decision-making. As a result, an environment had to be identified and designed to support sector managers in decision-making. Thus, our aim in this research was on the need to present relevant product(s) or artefacts such as a "water asset management decision enhancement environment" as perceived by sector managers. The initiation stage, therefore, involved a pilot study to test the research instrument and gather information prior to undertaking a larger study. This was done to improve the quality and efficiency of the data collection methods and this was conducted with sector managers at the National Water and Sewerage Corporation (NWSC). Permission to carry out data collection was sought and granted in three water utilities: NWSC, Uganda; Rand Water, Johannesburg, South Africa; and Waterbedrijf Groningen, The Netherlands. Preliminary interviews and recent literature review were then conducted. The initiation stage was vital for achieving the set goals.

Abstraction Stage

The abstraction stage includes an analysis of a proposed solution, explored mainly to guide the researcher to gain better understanding of different dimensions of the problem (Ahuja, 2009). It also involves using a decision enhancement lens to understand the issues in water asset management. At this stage, the author derived requirements for an environment to support sector managers' decision-making in water asset management leading to a descriptive conceptual model. The abstraction process assists in determining the best research design, data collection method and selection of research respondents (Gregory, 2010). Abstraction was achieved through interviews, observations, focused group discussions and literature review presented.

Theory Formulation

In theory formulation whose output was a prescriptive conception (design), the author considered a new purposeful artefact to address issues of decision-making relating to asset maintenance, investment planning and risk management derived from the requirements and the perceived solution to form a general theory. Venable and Baskerville, (2012) affirm, "that a purposeful artefact refers to any kind of artefact designed to achieve some human purpose". In this regard, the author considered the water asset management decision enhancement solution as that purposeful artefact. Consequently, the result of the theory formulation process is a conceptual prescription for the problem domain. At this stage, the author particularly describe the service values that the studio may deliver to sector managers, important activities to be performed, identify resources that are required including a preliminary implementation scope whose details are presented in Chapter 4.

Consequently, at the theory formulation stage, the authors introduce an approach to design the Decision Enhancement Studio for Water Asset Management (DES-WAM), which employed the inductive-hypothetic research strategy. It involved gathering of information for the actual elicitation of sector managers' decision needs through exploratory studies. Additional consultations with domain experts was undertaken to refine the problem scope and verify the proposed theory.

Prototyping, Implementation and Evaluation

Throughout the design phase, multiple studio designs were created prior to arriving at the version presented in this research. First, a studio prototype was deployed at the Water and Operations Unit of NWSC in Kampala to refine the studio design. The NWSC case initial tests resulted in design considerations as well as evaluation concepts. Consequently, comments for refinement captured in the initial deployment were quite useful in improving the latter designs. A studio prototype aimed at decision enhancement for WAM was developed and implemented in three water utilities, namely Nairobi City Water and Sewerage Company (NCWSC), Kisumu Water and Sewerage Company (KIWASCO) and National Water and Sewerage Corporation (NWSC), Kampala.

Instruments

Instruments are described as specific methods that are used to execute a particular research strategy (Gonzalez, 2010). This research consists of several phases to create the studio for decision enhancement and facilitate complex asset management decision processes while providing architecture of services for decision-making which are evolving and progressive towards asset management for water utilities.

Table 1-2 derived from Gonzalez (2010), shows specific methods that were used to execute the research strategy. It also shows the instruments that were adopted in each research phase including the corresponding outcomes. The forthcoming chapters of this thesis provide further details about how and why specific research methods were used.

Table 1-2: Research instruments and outcomes of the four phases of this research (Gonzalez, 2010)

Research Phase	Research Instrument	Outcome
Exploration	• Pilot study • Case Studies • Literature Review	• Refining the research instrument • Overview of water asset management challenges in transitional countries.
Understanding	• Literature review • Expert Interviews	• Understanding issues affecting asset management's decision processes and decision-making. • User and functional requirements
Design	• Literature Review • Expert Interviews	• Asset management decision theory • Design considerations

Research Phase	Research Instrument	Outcome
	• Case Studies • UML Process Modelling	• Studio designs
Implementation	• HTML5, JavaScript, PHP, MySQL, Apache	• Decision enhancement studio
Evaluation	• Literature Review • Case Studies • Expert Testing • Expert Interviews • Questionnaires	• Testing • Evaluation results regarding the studio's effectiveness (usefulness and usability) • Conditions for successful studio deployment

1.6 Thesis Outline

This thesis is organized in seven chapters. Chapter 1 introduces the asset management domain, decision enhancement, research problem, research objective, and approach. Chapter 2 explores the theoretical underpinnings on asset management decisions. Following the inductive-hypothetic research strategy of Sol (1982) Chapters 3 to 6 deal with the four phases of this research being exploration, understanding, design and evaluation. Finally, chapter 7 provides an epilogue.

Chapter One: presents a brief introduction exploring succinct aspects of water asset management in transitional countries. It also looks at the focal point of the study, which covers discussions on decision enhancement. The chapter states the research problem and research objective. It goes on to present the research approach which covers the research philosophy, strategy, and instruments. Finally the chapter ends by presenting the thesis outline.

Chapter Two: focuses on reviewing theories on asset management decisions. It also defines the terminology of key terms used in the study. Theories on asset decisions are discussed. A close look at key influencing factors to water asset management is discussed.

Chapter Three: delves into the presentation of the results and an analysis of the findings. The chapter provides the results of the exploration and understanding research phases. In this chapter, a categorization of water asset management decision-making challenges, observations regarding asset management decision-making, and

functional studio requirements are presented, addressing the research objective of this research.

Chapter Four: presents the design of the decision enhancement studio for water asset management. It comprises the different ways of thinking, governance, working and modelling.

Chapter Five: explains the approach undertaken in implementing the WAM studio prototype. It describes the WAM studio prototype and its implementation considerations.

Chapter Six: describes the methods engaged in testing the WAM studio. The evaluation approach is elucidated. Designing of the test sessions for the studio to capture the operational, tactical and strategic levels and the findings are provided. Evaluation results regarding the studio's effectiveness (usefulness and usability) are discussed as well as the conditions for successful studio deployment.

Chapter Seven: winds up the study by: presenting the research contributions, discussing the findings of this research, and providing a summary of the answers to the research objective. Furthermore, reflections regarding the adopted research solution as well as suggestions for future research are explored.

CHAPTER 2
ASSET MANAGEMENT DECISIONS

The chapter entails a review of research into water asset management decisions supported by information systems. In section 2.1, the author defines asset management. Section 2.2 highlights the importance of asset management while section 2.3 presents asset management specifications. Section 2.4 focuses on the benefits of asset management while section 2.5 dwells on asset management implementation. The factors influencing asset management are discussed in section 2.6. The chapter ends by explaining decision support systems for asset management in section 2.7.

2.1 What is Asset Management?

Asset management, in the context of physical assets, is a systematic, structured process covering the whole life of physical assets, whereby the underlying assumption is that assets exist to support the organization's service delivery strategies, and require a certain level of management insight and expertise from diverse organizational disciplines (CIEAM, 2008). Since the 1990s, it has been argued that effective and optimal management of physical assets requires an interdisciplinary approach (Amadi-Echendu et al., 2007; Wittwer et al., 2002) to ensure that an appropriate mix of skills can be brought to bear in resolving the complex issue of asset management (Amadi-Echendu et al., 2010). By deciphering this complexity, organizations can optimize their asset management processes, thus producing increased levels of efficiency in areas of their asset management (Frolov et al., 2010). Consequently, it is no longer sufficient to consider asset management simply as the maintenance of an asset (Amadi-Echendu, 2004), but rather as a holistic approach to the management of assets. It incorporates elements such as strategy, risk management, safety, environment and human factors (Frolov et al., 2010). The new orientation has been on developing a range of strategic responses to safeguard the large public and private investments in assets.

On the other hand, Lloyd (2012) defines asset management as the art and science of making the right decisions and optimizing decision processes. A common objective is to minimize the whole life cost of assets but there may be other critical factors such as risk or business continuity to be considered objectively in this decision-making. Lloyd adds

that this emerging professional discipline deals with the optimal management of physical asset systems and their life cycles. Within the context of British Standards Institute PAS55 (BSI, 2008), asset management represents a cross-disciplinary collaboration to achieve best net, sustained value-for-money in the selection, design, acquisition, operation, maintenance and renewal/disposal of physical infrastructure and equipment.
The new international standard for asset management, ISO 55000 (2014), defines asset management as a "coordinated activity of an organization to realize value from assets". PAS 55 gives a more expansive definition, "systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan" (British Standard Institute [BSI],2008).

Asset management is a recent way of thinking, so it is understood that people practicing it have to think in an innovative way about the situation their organization is in and how to improve it (Lloyd, 2012). A proactive approach to change management of organizational culture is essential to embedding asset management thinking and practices.

2.2 Why is Asset Management important?

According to an audit of asset management for public entities in New Zealand, asset management is important for a number of reasons (Mana, 2010). First, many public services rely on assets to support their delivery. Unless the assets are well managed, the services they support will suffer. Secondly, assets represent a significant investment by stakeholders that needs to be protected. Thirdly, assets are often taken for granted until they fail. A failed asset can have both social and economic effects on the country. To avoid this kind of situation, someone has to keenly manage assets. Therefore, asset management integration into the organization is now a fundamental issue concerning organisational performance (AAMCoG, 2012).

Mana (2010) further explains that asset management must become part of the culture, that is, the way things are done in a given institution. It is fundamental to plan effectively and

such planning needs to be recognized. It is not something done only to comply with legislation. Leaders need to buy into the process, understand its significance and the value of its outputs. This is not costly but requires a change of mind-set and a vibrant leadership.

An effective organization needs to recognize that asset management is an integrated process, which cannot function in isolation (AAMCoG, 2012). No one part should happen without the others or is intrinsically more important than the others. This teamwork process involves engineers, financial and corporate planners, and policy makers.

2.3 Asset Management Specification

The British Standards Institution (BSI) for the Publicly Available Specification (PAS) for the optimized management of physical assets (BSI, 2008), as a specification, has been increasingly recognized as a basis for good practices in asset management (Woodhouse, 2010). This publicly available specification (PAS) was first published in 2004 and revised in 2008 in light of increasing international consensus on good practices in the management of physical assets (BSI, 2008). Since PAS 55 was created, though lacking in detail, it demonstrated success (Van Grunsven, 2012). As observed by its fast take-up in different industrial sectors, it established value in breaking down silos within organizations, forcing long-term thinking and encouraging net value-for-money to be the basis for cost, risk and performance decision-making (Woodhouse, 2010).

A practitioner can also use PAS 55 as a benchmark tool to identify potential gaps in their overall asset management practice compared to best practice asset management publications (IAM, 2004). Therefore, this is significant to stakeholders in building a foundation for the development of asset management process patterns, which encapsulate asset management processes common to different types of several industries.

2.4 Benefits of Asset Management

According to ISO 55000 (2014), benefits of asset management are varied. These are illustrated below.

Improved financial performance: improving the return on investments and reducing costs can be achieved, while preserving asset value and without sacrificing the short or long-term realization of organizational objectives.

Informed asset investment decisions: these decisions enable the organization to improve its decision-making capacity and effectively balance costs, risks, opportunities and performance.

Managed risks: it involves reducing financial losses, improving health and safety, good will and reputation, minimizing environmental and social impact. These could result in reduced liabilities such as insurance premiums, fines and penalties.

Improved services and outputs: assuring the performance of assets can lead to improved services or products that consistently meet or exceed the expectations of customers and stakeholders.

Demonstrated social responsibility: this includes improving the organization's ability to reduce emissions, conserve resources and adapt to climate change. It also enables one to demonstrate socially responsible and ethical business practices and stewardship;

Demonstrated compliance: it includes transparently conforming to legal, statutory and regulatory requirements, as well as adhering to asset management standards, policies and processes.

Enhanced reputation: it enhances reputation through improved customer satisfaction, stakeholder awareness and confidence

Improved organizational sustainability: this involves effectively managing short and long-term effects, expenditures and performance, which can improve the sustainability of operations and the organization.

Improved efficiency and effectiveness: reviewing and improving processes, procedures and asset performance can improve efficiency and effectiveness, and the achievement of organizational objectives.

While the Environmental Protection Agency (2008) describes the benefits of asset management as prolonging asset life and aiding in rehabilitating, repairing or replacement decisions through efficient and focused operations and maintenance. They also include meeting consumer demands with a focus on system sustainability; setting rates based on sound operational and financial planning; budgeting focused on activities critical to sustained performance; meeting service expectations and regulatory requirements; improving response to emergencies and improving security and safety of assets.

Asset management offers investors and other stakeholders a rational set of principles for defining how corporate goals can be achieved and how the value of a business can be confirmed (Lloyd, 2012). These practices can be based on asset management systems through which businesses focus on services rather than engineering and reduce their exposure to risk at the same time as they reduce operating costs and capital spending (Lloyd, 2012).

2.5 Asset Management Implementation

ISO 55000 is the first worldwide attempt to capture the generically applicable essential items for management of any asset type (Transition guide, 2014). ISO 55000 offers the basic principles of asset management, the benefits that such a system offers and outlines different management levels of an organization (Van de Honert et al., 2013). ISO 55001 specifies minimum requirements to establish, implement, maintain, and improve an asset management system. These requirements enable both internal and external parties to measure an organization's ability to meet legal, regulatory, and contractual requirements as well as the organization's own requirements (Van de Honert et al., 2013).

ISO 55002 offers guidance on how to apply an asset management system in accordance with the requirements of ISO 55001 (Van de Honert et al., 2013). According to Van de Honert et al., (2013), ISO 55001 and ISO 55002 are divided into seven main elements:

organisational context, leadership, planning, support, operation, performance evaluation, and improvement. To utilize the benefits of asset management fully, the strategy for implementation should be integrated with the greater business plan and other management systems of the organization (Van de Honert et al., 2013).

2.6 Key Influencing Factors in Asset Management

The Asset Management Function

Asset management activities permeate many levels of an organization, and are not confined to a central group (Hasting, 2010). For this reason, it is advisable to use the term Asset Management Function as a flexible descriptor for the activities involved and to apply the term Asset Manager to those involved, but not necessarily exclusively, in asset management activities.

Hastings (2010) explains that the purpose of the Asset Management Function is to provide resources and expertise to support the acquisition, in-service support and disposal of the physical assets required by the organization. Therefore, a central asset management function is required at company level to provide inputs to asset planning take a role in major acquisitions, and developments and provide the systems and facilities needed to support assets throughout their life. Consequently, asset management is distinct from operations and does not usually involve the direct design or building of the assets themselves. It is also normally distinct from maintenance, but the technical services functions, which support maintenance, are part of asset management. The exact terminology and reporting structures may vary from organization to organization.

Asset Management Structure

Asset management activities and responsibilities influence a wide range of roles within an organization and are not confined to a specific department. An asset management team consists of asset managers with suitable technical backgrounds, and personnel in accounting and finance, legal, contracting, procurement and engineering disciplines (Hastings, 2010). As a result, the financial, legal and engineering staff will be assigned to asset management teams from their professional area. Thus, the asset management teams

form a basis from which these sets can be formed. Therefore, asset management groups have key roles in acquisition and development decisions and projects, and in creating and managing organization-wide systems for equipment support for new and existing assets.

Asset Management Strategy

A strategy is a broad level plan set by senior management as a guide to how an organization intends to achieve its aims (Hastings, 2010). Consequently, the strategy sets out the procedures, or refers to existing documents, which specify procedures to be followed, and specifies authorities and responsibilities for action in relation to asset management activities. These may be incorporated in a general manner based on such documents as organization charts and job descriptions; however, it is important that the asset management aspects be covered in managing assets.

Political Will and Accountability

Public officials at all levels of government and the communities they serve can take steps to engender the public climate and build the political will necessary to guarantee water systems for future generations (CAI, 2013). The role of governance in determining service coverage and access to water is well-recognized, and has been used to explain the uneven landscape 'behind the scenes' of global WASH success (UNDP, 2006). A growing population, poverty, government water and energy subsidies, failure to price the resource, over consumption, and an overall failure of political will and governance have contributed to "an inexorable planetary crisis" (CAI, 2013). All levels must commit to asset management in order for it to be successful, namely from politicians who ensure political will, legislative compliance and community requirements, to planning by management and implementation at the operational level (Bhagwan, 2009).

From a sociological perspective, public sector managers should be accountable in different areas (Mohammadi, 2011). The question is to whom should they be accountable and how can this be assessed? In a democratic system, public sector managers are faced with at least five kinds of accountability (Mohammadi, 2011): organisational, political, legal, administrative and professional accountabilities.

Accountability aims to raise the bar in asset management practice in that it sets out the need for utilities to establish appropriate systems and controls, and to institute specific accountability and transparency provisions (Bhagwan, 2009). Accountability is key to maintaining relationships with utility management and investors and it will always remain with the company staff.

Policies, Planning and Coordination

Policy refers to the intentions and direction of an organization, formally expressed by its top management (ISO 55002, 2014). ISO 55002 offers guidance on how to apply an asset management policy in accordance with the requirements of ISO 55001. Top management should authorize the asset management policy; thereby demonstrate commitment to asset management (ISO 55002, 2014).

The policy should be communicable to the organization. There should be processes in place to review and update the asset management policy, and to ensure that if the organization's external or internal context changes, the actions necessary to update the policy are also triggered (ISO 55002, 2014).

Asset management planning involves stages: assessing the readiness of the firm for asset management, justifying the benefits and costs, obtaining support from management, developing the scope, and creating roles and responsibilities for development and support staff (Mathew et al., 2006). In the same vein, there must be strong support from management, and ownership from the organization starting from the inception phase of asset management. It is recommended that there be facilities to acquire early and on-going feedback from stakeholders.

While several published reports of information systems are being utilized by the water utility industry, most of them fall short of implementing systems that deal with asset management decisions (Mathew et al., 2006). Others have limited scope of the asset management component, and leave a significant gap for a structured approach to the improved integration of different asset lifecycle areas.

Collaboration among Stakeholders

Collaboration among stakeholders on decisions that matter is important in instituting asset management practices amongst utilities. Collaboration goes beyond people participating in the process (Keen & Sol, 2008). It extends beyond communication, cooperation, and coordination, even though these are critical elements in the process.
Collaboration refers to a mutually beneficial relationship between two or more parties who work towards common goals by sharing responsibility, authority, and accountability for achieving results (World Wildlife Fund, 2000). Carpenter (1990) gives the key characteristics of collaboration: inclusive and non-hierarchical participation; participant responsibility for ensuring success; a common sense of purpose and definition of the problem; participants educate each other; the identification and testing of multiple options; participants sharing in the implementation of solutions and people are kept informed as situations evolve. The need for effective internal collaboration in decision enhancement takes into account these characteristics as well as objectives of stakeholders while at the same time delivering asset management benefits to them.

There is flexibility within the decision enhancement environment to support sector managers at the strategic, tactical and operational levels in their decisions processes (Keen & Sol, 2008). There are challenges in water companies with systems that do not talk to each other, for instance, there are limited monitoring systems and methods that provide the necessary tools for data analysis which would enable managers to make decisions and cut back on response time.

Management of Change in Asset Management

Internal or external changes affecting assets, asset management or the asset management systems can affect the organization's ability to achieve its asset management objectives. These changes ought to be evaluated and mitigating actions taken prior to implementation (ISO 55002, 2014). The organization should have the capability to make evidence-based decisions on proposed changes and systematically consider scenarios across the entire organization (ISO 55002, 2014). Risks associated with a change should be considered in relation to their impact on asset management and the asset management system (ISO 55002, 2014).

Outsourcing Asset Management

Outsourcing is a common method for an organization that prefers not to perform certain asset management activities on its own, but by an external or internal service provider (ISO 55002, 2014). When these activities influence the achievement of the asset management objective, these should be part of the asset management system, and should be documented. Any asset management objectives, processes and activities that are outsourced should be controlled by the organization to provide assurance that performance is as planned. The extent of outsourcing could require a service provider to establish its own asset management system that is aligned with the organization's asset management objectives (ISO 55002, 2014).

The organization ought to consider the ownership and protection of intellectual property and corporate knowledge while outsourcing asset management activities (ISO 55002, 2014). Policies in relation to outsourcing and retention of specific sets of skills within the organization may then be established (Hastings, 2010).

Readiness for Asset Management

When introducing asset management to an organization, there are four stages: awareness, interest, inquiry and commitment (Lloyd, 2012). During the awareness stage, a company merely becomes aware of the existence of asset management. The specific awareness needs of any stakeholder should be determined by their role and its relationship to the organization (ISO 55002, 2014).

The interest stage depends heavily on the sales and marketing efforts of consultancies and software firms, the networking and initiatives of professional bodies, regulator and government initiatives, pressure from investors and banks and, above all, a perception among senior managers that asset management might be able to make a significant contribution to the company's financial performance (Lloyd, 2012).

During the third stage of inquiry, a company is ready to assess, in a systematic manner, how asset management thinking and practices might be configured to suit its purposes (Lloyd 2012). Most companies find it difficult to estimate the financial impacts;

moreover, all companies have difficulties in predicting the benefits. The business case for asset management ought to be based on identified requirements, specific outcomes and expected benefits with timescales (Lloyd, 2012).

The commitment stage involves the company committing itself to change (Lloyd, 2012). PAS 55 has proved invaluable in this regard, symbolizing both openness to external best practices and a depth of management support (Lloyd, 2012).

2.7 Decision Support Systems for Asset Management

Risk-based prioritization

Lloyd (2012) explored a number of companies engaged in asset management and the systems they use to support decisions for their assets. He found out that the focal point of UK's Wessex Water Utility in the development of the company's asset management capabilities has been risk-based prioritization of maintenance and investment. The objective was to improve understanding and management of risks to service associated with operational activity and external factors. An iterative approach that built on external initiatives from environment regulators, such as water protection plans, water distribution networks' operational and maintenance strategies (DOMSs) was taken. Modelling and analytical tools were developed to prioritize operational maintenance response and investment, by allowing a consistent way of assessing the impact and likelihood of service failure across all the company's physical assets at an operational, tactical and strategic level. The tools also allowed a review of all emerging customer, environmental, legal and regulatory risks; reporting to senior management and the board on strategic high-level risks and mitigation measures. The outcome of these processes and tools is a 'heat map' report that allows a simple representation of the company's aggregated risk position by using colours to show the severity of the risk positions for the company's service standards and industry drivers (Lloyd, 2012).

Effective planning

UK's South West Water (SWW), in partnership with AECOM, developed a number of custom-made planning and investment tools that it uses to produce detailed specifications

of its sewerage infrastructure investment needs, underpinned by a comprehensive understanding of asset risk. The sewerage economic assessment model (SEAM) is an asset management process developed by AECOM to help SWW address flooding and pollution risk on its sewerage networks (Lloyd, 2012). SEAM is used to identify, quantify and assess failure risk leading to the scoping and costing of outline engineering interventions to address flooding and pollution problems. SEAM has since been fully adopted as a SWW business-as-usual planning methodology. Its outputs are used to populate its asset management capital investment plan and support its PR14 business plan submission to Ofwat (Lloyd, 2012). SEAM is being used by SWW as a tactical tool to plan investment to address flooding and pollution issues. Historic failure data are plotted in a geographic information system (GIS) environment (Esri, 2012). A buffering process is used to identify hotspots representing areas of risk failure. Failure thresholds are applied to avoid an overload of low-level risks. A desktop engineering study is completed for each catchment to assess flooding and pollution hotspots, quantify the associated risk and drive specific intervention options to address these risks. The risk model also calculates the associated financial benefit to SWW to resolve each specific flooding or pollution issue. Interventions are then costed. The SEAM process and study outputs are integrated into the asset planning and capital delivery process. Tactical outputs from the catchment studies are fed into the SWW investment management system, which identifies high-priority SEAM interventions and passes them to the capital plan for asset management plan delivery (Lloyd, 2012).

Investment optimization

Decision-making and planning for sewerage asset renewal is a process that seeks to evaluate the condition of an asset, its risks of failure and the cost of remediation (Ward et al., 2014). An asset investment decision environment (aiDE) has been developed within Microsoft Excel to permit the application of a multi-objective optimization tool to sewer rehabilitation planning (Lloyd, 2012). Engineers and planners are using this new approach to assist in the identification and delivery of SWW's multi-million pound sewer rehabilitation programme. Within this programme, the tool acts as a quantitative mechanism for evaluating different work programmes and justifying rehabilitation

programme decisions on the ground of cost minimization, structural condition improvement and risk aversion. aiDE capitalizes on the availability of standardized CCTV condition grading information, which has been recognized as the single most important element of information used by planners, engineers, consulting engineers and contractors in helping to ascertain the condition of sewage assets (Kawalec et al., 2012).

The current method of sewer condition classification (MSCC4) widely used and accepted condition grading format in the UK, produces a computer-coded output tabulating the observed defects and their extent (WRc, 2004). The sewer rehabilitation optimization model orients engineers towards high-benefit-low-cost solutions that could not otherwise be identified. It is a decision support tool that enables a cost-benefit trade-off based-solution evaluation for an array of rehabilitation solutions at the catchment level (Lloyd, 2012).

Monitoring water networks for water loss detection

Takadu has helped Londoners save water (Moskvitch, 2011). It is an innovative solution to detect leaks, eliminate them as soon as possible in order to reduce operational costs. Takadu aims to save water by monitoring the infrastructure and detecting leaks in pipes early enough. Spotting leaks early was tricky. For example, Thames Water was unable to meet leakage reduction targets from 2003 until 2006, according to the water services watchdog Ofwat (Moskvitch, 2011). The time taken to find leakage hotspots was halved for the Thames Water after installing a Takadu infrastructure monitoring system across the whole of London.

The devices work as a ‘smart grid’, fitted with a hi-tech ‘central nervous system’ that detects hot spots under the streets of London (Moskivitch, 2011). Thames Water’s partnership with Takadu water infrastructure monitoring system enables it to monitor water flow and pressure changes in a main line in a water supply system and analyses real-time data and historical data to detect potential problems ahead of time (Moskvitch, 2011).

Whereas the current guidelines like PAS 55 and ISO 55000 provide standards on asset management, they are lacking in detail. They do not address themselves on the "how to" of asset management (Van Grunsven, 2012). Today, water companies are more focused on engineering solutions while putting little emphasis on services. Lloyds (2012) observes that businesses should focus more on services rather than engineering in order to reduce exposure to risk, operating costs and capital spending. Consequently, our research seeks to provide services that support decision-making issues highlighted in Chapter 1. Thus, there is need for an environment, which provides services to support facilitation, provide guidelines on asset management and solutions in asset maintenance in order to reduce operational costs and capital spending and risks. In chapter 3, the author discusses the exploration of asset management environments.

CHAPTER 3
EXPLORATION OF ASSET MANAGEMENT ENVIRONMENTS

This chapter discusses the exploratory study conducted in Sub-Saharan Africa and Europe. Section 3.1 explains how the studies were performed. Section 3.2 reviews the case of Rand Water, Johannesburg South Africa. Section 3.3 looks at the case of Waterbedrijf Groningen, the Netherlands. Section 3.4 discusses asset management at National Water & Sewerage Corporation, Uganda. Section 3.5 examines other cases in Sub-Saharan Africa that attended an asset management workshop in Johannesburg. Section 3.6 outlines the water asset management challenges in the water utilities. The characteristics of an ideal asset management decision studio are presented in section 3.7 and the decisions to be supported by the WAM-DES are presented in section 3.8.

3.1 Study Approach

Study Setting

The exploratory strategy was applied to three water utilities including the National Water and Sewerage Corporation (NWSC), Uganda; Rand Water (RW), Johannesburg, South Africa and Waterbedrijf Groningen (WBG), The Netherlands. RW and WBG were mainly researched for benchmarking purposes and also identifying best practices in water asset management. In-depth knowledge about how water utilities shape the implementation process of asset management is required to develop targeted services to ensure that decision enhancement is enabled amongst the stakeholders.

To address the research objective, a survey of water utility participants was designed and administered and the responses received were analysed. The survey respondents were selected to represent three classes of sector managers; managers at the strategic level, tactical level staff and operational level staff. For managers at the strategic level, strategic plans normally require multi-level involvement so that each level of the organization plays a significant role in achieving the goals. Therefore, they were chosen because of their roles in performance measurement as strategic managers. Tactical level staff is also responsible for financial results, progress control and failure analysis, that is why their roles were included.

Operational level staff were selected because they control and regulate day-to-day output relative to schedules, specifications and costs in the water utility. In all, 37 sector managers were included in the sample.

Data was gathered using structured interviews (see Appendix B), an asset management workshop, seminars, focus group meetings, field visits, observations and literature review. Managers were chosen to be the respondents of this study typically because managers are the main decision-makers in water utilities.

At Rand Water Johannesburg (RW) interviews were conducted in November 2011 (n=12), while for Waterbedrijf Groningen (WBG), interviews were conducted from March to April 2012 (n=10). At the National Water and Sewerage Corporation (NWSC) interviews were conducted between July and October 2012 (n=15). The respondents in their various categories are as follows: 11 at the operational level, 10 at the tactical level and 6 at the strategic level, totalling to 27 participants at only one managerial level. Additionally, 10 participants belonged to more than one managerial level, that is, 7 participants belonged to 2 managerial levels (strategic and tactical: 3; tactical and operational: 4), and 3 participants belonged to all levels of management (see Appendix A).

At Rand Water all participants belonged to only one managerial level which is attributed to their structured approach to asset management. This provided clear requirements for water asset management at the different levels. At Waterbedrijf Groningen and National Water and Sewerage Corporation some participants belonged to 2 or 3 managerial levels. This enabled exploration of linkages/interaction of requirements between the levels during water asset management. Managers at the strategic, tactical and operational levels were interviewed because decisions on asset management are cross cutting. Qualitative data was analysed using open coding and NVivo, while quantitative data was analysed using SPSS Version 16.

Criteria for selecting participants

The case studies were selected based on their status in practicing water asset management. Case study respondents were selected basing on their availability,

involvement and experience in asset management (idealness), and willingness to share institutional knowledge (Veser, 2004). Snowball sampling was employed because the target population was unknown to the researcher (Ahuja, 2009). The snowball technique was handy in overcoming problems associated with sampling concealed populations as well as taking advantage of the social networks of identified respondents to provide the researcher with an ever-expanding set of potential contacts (Thompson, 1997).

Using the snowball technique, the researcher began the research with a few respondents that is, managers as decision-makers at the various managerial levels of strategy formulation, tactical and operations maintenance personnel, recommended by the research managers at the respective water utilities. Subsequently, these respondents gave other names who met the criteria of research, who in turn gave more new names. This process was continued until adequate numbers of persons were interviewed. Participants would typically develop ideas triggered by other participants (Vogt, 1999).

Furthermore, participants from the operational, tactical, strategic managerial levels were selected because each of these levels had a role to fulfil in the relevant business processes and involved undertaking activities, including: 1) the collection and capturing of operational data; 2) tactical decisions and the management of day to day tasks and schedules; and 3) the medium to longer term decisions regarding infrastructure maintenance. Representatives from different functions were included (e.g. Asset Management; Maintenance; Water Quality; Strategy; ICT, Call Centre, and Planning). The 3 levels and the variety of functions were included in the scope to ensure that the research explored and understood the requirements of the various functions and management levels, as well as to ensure that the studio is evaluated from the different perspectives. These findings will lead to the elicited requirements that will be used in the design of the studio.

3.2 Rand Water, South Africa

Since 1903, when gold was discovered, Rand Water has been in operation distributing water to local authorities, the mining industry and other large industrial concerns in the

province of Gauteng, Johannesburg, the economic heartland of South Africa (Lange and Kasam, 2014). Rand Water has been in existence for 110 years and continues to grow.

During 2011, the operations of Rand Water Services (Pty) Ltd were integrated into Rand Water. Rand Water Services (Pty) Ltd was formed in 2000 to develop and pursue the commercial aspects of Rand Water's business in the water services industry (Rand Water, 2011). Rand Water is the largest water utility in Africa having a bulk water supply to 12 million people including the metropolitan areas of Johannesburg and Pretoria, and more than 3000 employees at 18000 square km. It has engineering expansion schemes of 4400 million litres produced per day. Rand Water abstracts its raw water from the Vaal Dam via a canal and a gravity pipeline; the water is pumped from the Vaal River Barrage Reservoir at Lethabo, Zuikerbosch and Vereeniging. A small quantity of water is also abstracted from underground sources at Zuurbekom (Lange & Kasam, 2014). Rand Water's core business is about raw water abstraction, purification using chemicals and pumping to distribute it to the users (Rand Water, 2013).

The National Water Services Act 108 of 1997 allows for the establishment of water boards to assist the local government sphere to meet its constitutional obligation of effective, efficient, sustainable and affordable service delivery. The Act requires Rand Water to ring-fence other business activities from the regulated water services (Rand Water, 2011).

Rand Water extracts an average of 3 500 Mℓ/d from the Vaal River, treating it to potable standard, and pumping it nearly 400 m upwards to the service reservoirs, 65 km and further away at the local municipalities, that in turn distribute it to nearly 12-million users. The reliability of its major pipelines is of obvious great importance to the national economy, and the asset management regime of these pipelines therefore needs to be of a very high order. Management of the major pipelines is dependent upon reliable and comprehensive information and a disciplined approach to operational and investment decisions (Bhagwan 2009).

Rand Water turnover is in excess of R 3 billion (equivalent to US $ 400 million) per annum, and the substantial surplus which is generated, year after year, is either re-invested or committed to accumulated reserves (Rand Water, 2012). As a result, Rand Water is financially secure and continuously enjoys the highest credit rating in South Africa. Therefore, its financial robustness gives it the freedom to treat infrastructure as a valuable long-term investment and to make decisions based on optimizing the service life cycle of the infrastructure. Concerning a disciplined approach to asset management decisions, for example, advocacy of comprehensive information is utilized to identify the problem probability profiles of all significant infrastructure elements.

Strategic importance of these infrastructure elements is also identified, and the risks, namely the consequences of infrastructure failure, are matched with the problem probability profiles. The type of attention is identified, in order to specify priority, namely, to consider the alternatives and options to cover the identified risks. Operational and investment decisions can then be based, with confidence, on this reliable and comprehensive information.

The best practice innovation point is that Rand Water pipeline asset management represents best practice water service infrastructure asset management in South Africa. There is no substitute for the underlying factors that enable Rand Water to manage its assets in this way. These factors include financial stability, top management‘s willingness to budget adequately for infrastructure asset management, sufficient technical capability to advise, plan, and implement as well as procuring and supervising outsourced skills.

Asset Management Implementation Process

Rand Water adopted the understanding that Asset Management comprises systematic and coordinated activities and practices through which they optimally manage assets, their associated performance, risks and expenditures over their lifecycles to achieve its organisational strategic plan (BSI, 2008). It is a holistic and integrative approach to the managing of assets over its whole life, from inception to disposal. It is a strategic

discipline which enhances the quality of decisions made by organizations concerning their assets.

Rand Water can be defined by the size and value of its infrastructure or fixed assets and its dependency on the performance of these infrastructure assets and the intention and efforts to maintain these assets in order to provide a specified level of service (Rand Water, 2013). Consequently, the replacement value of the infrastructure assets is estimated to be worth ZAR 80 billion (Rand Water, 2013). In 1965, Rand Water was supplying 1,000 Ml/d; since then demand has increased four-fold to approximately 4,100 Ml/d in 2013 (Rand Water, 2013). As Rand Water enters a more mature phase, demand growth is projected to continue, but with a long-term decline in annual growth rates. Because of rapid growth in demand, much of the infrastructure capacity has been added in the last few decades. As rates of growth slowdown, the rate of adding infrastructure will also slow down, and the average age will increase. Management of the existing assets will be planned in conjunction with augmentation to meet demand growth (Rand Water, 2013).

Some of Rand Water's pipelines are 70 years old and the majority of pipelines are between 15 and 50 years old. At least 60% of the value of the Rand Water infrastructure resides in its pipeline. Less than 10% of Rand Water's 3,500km pipeline network consists of concrete pipes. However, the concrete and asbestos cement pipelines were identified as high-risk pipelines and these were replaced. As part of this process, Rand Water spent almost ZAR 1.75 billion in the 2012/13 financial year as part of its capital expenditure programme. This programme was designed to meet demand projections for water within its area of supply and to replace ageing infrastructure assets. The top five projects accounted for more than 40% of total capital expenditure and was focused on the Rand Water pipelines (Rand Water, 2013).

Rand Water had planned to spend ZAR14 billion on its infrastructure between 2013 and 2018 (Rand Water, 2013). Of this amount, 60% is allocated to infrastructure augmentation projects, with the remaining 40% allocated to infrastructure renewal

projects. An additional ZAR 5.8 billion is planned for the same period for growth related projects outside its core business.

A range of asset management related techniques and methods have been employed to protect the pipeline assets, assess the condition of the assets, prioritize and plan for the required renovation or replacement to optimize the use, or re-use of the current assets. A comprehensive asset register, broken down in terms of an agreed hierarchy of assets, and containing sufficient detail to allow proper lifecycle planning has been instituted. Agreed standards for design, specification, assessment and maintenance of assets are also in place at Rand Water.

Before 2012, Rand Water had some degree of asset management and processes in place that were documented but the approach was not structured. Asset management received a renewed focus and was established as an enterprise-wide imperative. Rand Water adopted the Publicly Available Specification for Asset Management (IAM, 2008) in 2012, as a framework for the implementation of structured asset management, and also adopted the ISO 55000, ISO 55001 and ISO 55002 standards in 2014 (ISO, 2014). Asset management policy, strategy and objectives were developed and approved in 2013. A governance structure for asset management was also implemented in 2013 including a multi-disciplinary Asset Management Steering Committee as a sub-committee of the Executive Management Committee of the organization. The maturity of asset management practices at Rand Water was independently assessed in November 2012. The assessment was done using 17 asset management key performance areas (KPAs) and a five-level maturity model (Rand Water, 2012). The overall rating was 2.4, between optimizing and preventing, and the result per KPA is represented in figure 3-1.

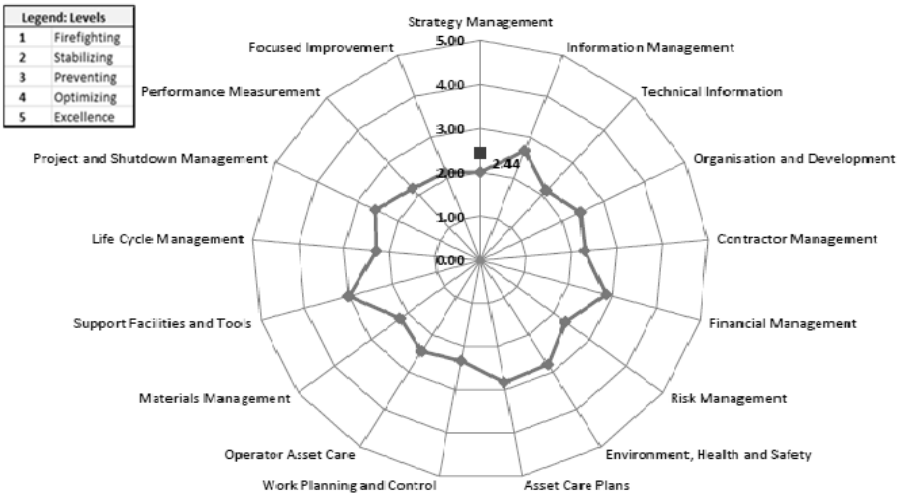

Figure 3-1: Rand Water's Asset Management KPA Maturity Assessment Results (Adapted from Lange & Kasan, 2014)

The maturity assessment is the basis for defining an improvement plan for asset management practices at Rand Water, with the aim of achieving at least a level 3 rating (Preventing) for all KPAs by end of June 2015 and a level 4 rating (Optimizing) for all KPAs by June 2018 (Lange & Kasan, 2014). The current asset management environment at Rand Water provides an excellent basis for establishing a more comprehensive and sophisticated asset management approach.

Achievements and impacts

Rand Water implemented large-scale formal asset management (AM) as a holistic practice across the organization following the PAS 55 specification (BS1, 2008). A new organizational structure was formed under a strategic asset manager (Senior Manager Assets) and a mandate given to implement best practice asset management. The new organizational structure led to some changes such as migration and office move, and recruitment of new personnel. It also included improvements on the design office structure, implementation of an asset management framework, role clarification regarding asset management and design, systems and tube diagram and organization-wide creation of asset management understanding (SAM, 2011). Challenges of the asset management

implementation process include management of change in roles and responsibilities, lack of expert design skills (Architecture, Electrical, Procurement, and Automation) and lack of Civil Asset Engineers (SAM, 2011) as shown in figure 3-2.

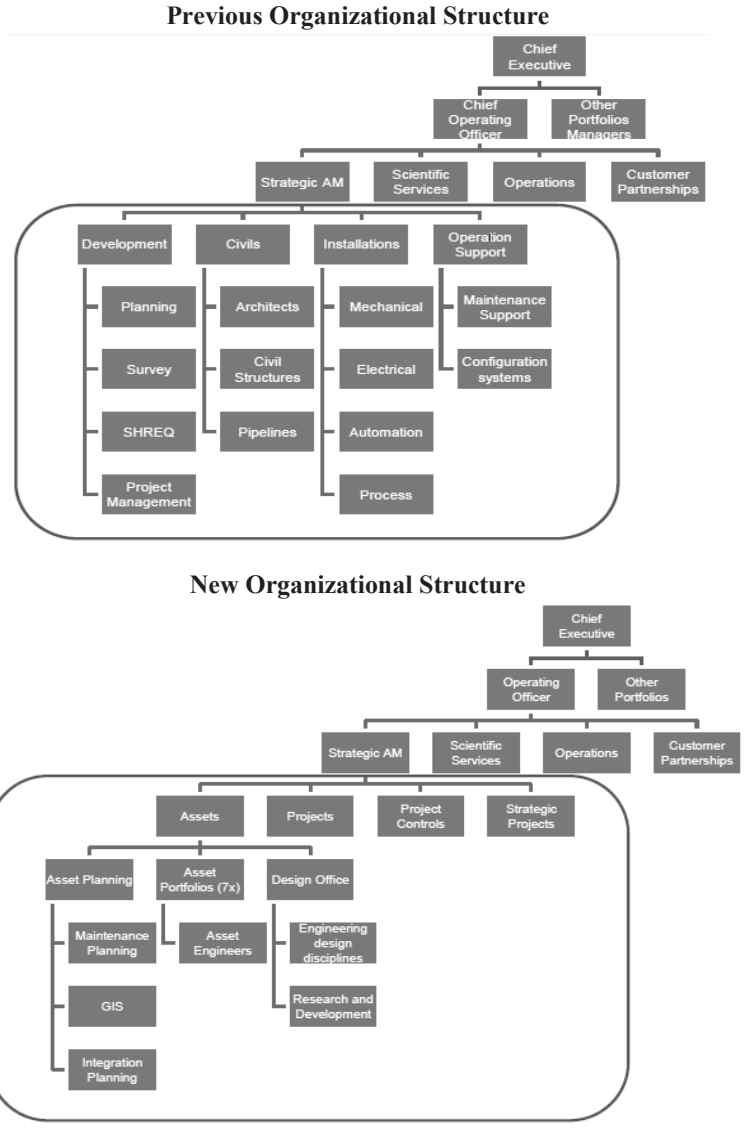

Figure 3-2: Rand Water's previous and new organizational structures (Lange & Kasan, 2014)

According to Rand Water (2013), the typical results achieved by the effective implementation of Asset Management are:

i). Increase in customer satisfaction, sustainability, profitability, availability, reliability, maintainability, resilience, flexibility, compliance, efficiency, effectiveness, safety, etc.

ii). Decrease in life cycle cost of assets, capital expenditure, operational expenditure, supply failures, asset failures, unplanned shutdowns, and carbon emissions.

iii). Towards the end of the reporting period, approval was obtained for the establishment of an Asset Management Steering Committee (AM Steercom), reporting to the Portfolio Integrating committee. The AM Steercom will consist of senior members from all areas of the organisation, in order to treat asset management as a business-wide imperative. The Steercom will set and delegate improvement tasks under each KPA, monitor progress and generally drive the implementation and integration of asset management as a way of life for the business.

Lessons learned

Communities are facing challenges relating to water and sanitation services provision in South Africa and Africa as a whole. The establishment of Rand Water's sector growth and development division is a response to these water-related challenges aimed at mitigating and negating their negative impact on the environment, society and economy (Rand Water, 2013).

Rand Water's growth thrust is founded on the expertise, which it has accumulated over the past years in the water business. It is therefore Rand Water's responsibility to identify the market needs and then package solutions properly in order to respond effectively and efficiently to what the national and international (Africa) water market demands (Rand Water, 2013).

Rand Water strategic growth imperatives are underpinned by the following salient factors (Rand Water, 2013):

i). Government is demanding greater support from State-Owned Enterprises (SOEs) to contribute to the national socio-economic development goals;

ii). Rand Water seizing a market opportunity to create water services capacity in areas where there is lack thereof, inefficiencies and losses;

iii). The need for Rand Water to diversify its service offerings and income stream; and

iv). Service delivery shortfalls present good opportunities for Rand Water to acquire new business.

3.3 Waterbedrijf Groningen (WBG)

WBG serves approximately 575,000 people in the province of Groningen in The Netherlands. Since 1878, the basis of WBG operational activities has been clean and reliable drinking water including security of supply and a sustainable approach to WBG raw products such as surface water and groundwater, to facilitate attainment of a long-term objective. WBG as a social enterprise broadly focuses on the sustainable protection of water interests. WBG and partners contribute to the sustainable development of the region with activities relating to drinking and industrial water, sewer systems, international cooperation and energy (WBG report, 2012).

The legal instruments at the disposal of water authorities are presented as the Water Act and its legal instruments. The Water Act of 29 January 2009 containing provisions for the management and use of water systems integrated eight previous sectoral water acts of The Netherlands (Mulder et al., 2011). The Water Act highlights integrated water management based on the "water system approach" addressing all relationships within water systems. Integrated water policy and management is reviewed in a six-year planning cycle and therefore simplifies the implementation of EU water directives such as the water framework (Mulder et al., 2011). The Minister for infrastructure and environment is responsible for the water management and development plan for the main waterways. Regional water plans and regional water management plans are the

responsibility of Provinces and Water Boards. The Water Act also provides the basis for the requirements to which water systems can be subjected.

The mission of Groningen Water is *Groningen Water as a social enterprise wants the water interests in the province of Groningen, safe and sustainable* and its Vision is, *Groningen Water supplies professionally high quality and reliable drinking water without profit to more than 265,000 connections in its service area*. Groningen Water strives to keep up with these aspirations. Costs are low for the customer and satisfaction with the service is equally important. Water extraction and environmental protection go hand in hand, therefore Groningen Water uses efficient and sustainable ways to extract natural resources and encourage water saving behaviour (WBG, 2012)

Process development

WBG has customized and adopted the PAS55 specification as a framework for the implementation of asset management. WBG has an Asset Management department with two full time employees, an asset manager and an asset management employee the two focus on the strategic, tactical and operational activities; evaluating infrastructure system performance; optimizing the overall system infrastructure and establishing frameworks and standards for maintenance and use. A distinction is made in a number of specific asset management tasks at the strategic, tactical and operational level. Strategic asset management focuses on the company and its stakeholders and results in the affordable price of Groningen Water. The supervisor and the Management Team (MT) complete the strategic asset management. Tactical asset management aims to reduce the overall infrastructure in order to focus the system to changing requirements to maintain compliance. Operational asset management focuses on the operation and maintenance of individual assets (exploitation). The objective here is to the existing assets to be utilized to contribute to the achievement of the overall system infrastructure (Groningen Water, 2008).

The strategic direction of Groningen Water is contained in the Company's Annual Plan. It is particularly important that asset management relates to the use of assets and the

primary process of water production and supply. Each year, the board evaluates the extent to which the strategic objectives have been achieved and whether adjustment of goals or direction is needed. Accountability to shareholders via the annual report of Groningen Water is mandatory.

The asset manager fills the role of tactical asset management. The asset manager translates strategic goals to performance requirements for drinking and industrial water infrastructure, performs integral system (risk) analyses, evaluates and assesses operating performance, performs life cycle costing analysis and proposes a multi-year water supply plan. Developments are particularly in terms of further implementation of reliability driven maintenance and use of pipelines and installations and the derived operational optimization measures.

At the tactical level, benefits to be gained are better coordination between the multi-annual investment and the future years of operation. This means that operating and investment costs resulting from the water supply plan are aligned with operating and investment resulting from the maintenance and use of existing facilities. The result at the tactical level is considered an integral Multi-year Investment Plan (MIP). It comprises investments resulting from new developments and investments from maintaining and exploiting existing assets such as replacement, investments and major modifications. The MIP sets frameworks for long-term multi-year exploitation plan (MEP). MEP includes operating costs of maintenance and use of existing assets and operating costs resulting from new developments. The management team of Groningen Water approves the MIP and MEP.

Embedding in the organization

Asset management was embedded at WBG in three different levels, namely strategic, tactical and operational (Figure 3-3).

Strategic: strategic asset management for drinking water rests with the board and the Management Team of Groningen Water. Industrial water's task is to fulfil its obligation

given by the Board and Managing Director of North Water. This conforms to the existing situation.

Tactical: informs the R&D department to accept responsibility for the implementation of tactical asset management for drinking water. For all tactical tasks, it was advised to fill the R&D department to expand by two FTEs, an asset manager and an asset management employee. Part of the implementation of various tactical asset management tasks in the future by other sectors and departments such as New Customer & Market are performed in accordance with the present situation. However, the responsibility for implementation, linking and matching the results and coordination of processes is at the Department of R&D. For industrial water, the tactical asset management tasks in the sector, Customer & Market are deposited where it comes to recruiting new customers, the mapping of customer requirements, maintaining customer relationships and the development of customer contracts. The technical oriented tactical tasks at the department of R & D are invested. Here, WBG aims at creating technical opportunities for win-win situations for drinking and industrial water.

Operational: pre-occupied with the operational assets of drinking and industrial waste water deemed necessary for the water modernising project. It is comprised of three FTEs: Process Engineer (Operations Department), Maintenance Engineer (Plant Maintenance Department) and Assistant KAM / Maintenance Policy (Infrastructure Maintenance Department). These functions are intended to guide policy for use and maintenance of facilities and distribution infrastructure to optimize systematic risk assessments, data recording and evaluation.

The key functions of Waterbedrijf Groningen are filling the traditional utility role as well as care for public health and welfare. WBG is a public, business-like and innovative company with deep roots in the region. In addition to WBG utility role, there are many challenges in the world of water: new environmental and spatial planning laws, changed requirements for the supply of drinking water an energy and the processing [and recycling] of industrial waste water, the climate discussion and changing customer needs. WBG translate these changes into the development of new products and services.

Naturally, this is done without losing sight of the basic function-the supply of drinking water.

Figure 3-3: Asset Management Process at WBG (Postmus, 2012)

Results and good practice

Groningen Water has joined forces with Evides and Water Supply Company, Drenthe into North Water to supply industrial water. The main objective of North Water is to be a reliable and competent partner for the supply of water to size and treating wastewater according to customer specific requirements.

The water supply chain is increasingly being approached as a single entity. It is important to organize partnership and synergy with and among all the parties involved. For that reason, Waterbedrijf Groningen established RioNoord in 2007, the sewer system company in which the Water Boards Hunze and Aa's and Noorderzijlvest also have a 50% share. RioNoord offers the opportunity to combine the knowledge, experience and workforce of the three parent organizations and the co-operating municipalities.

International cooperation

In the 'Schokland Agreement', the drinking water sector committed itself to the United Nations Millennium Goals (Van Velzen, 2012). Each year WBG is instructed by shareholders to contribute 0.5% of the annual turnover to international co-operation.

A DECISION ENHANCEMENT STUDIO FOR WATER ASSET MANAGEMENT

Waterbedrijf Groningen sets out to contribute to meeting the Millennium Development Goals.

WBG has contributed to the MDGs by:

i). Entering into partnerships with water operators, primarily in Eastern Europe;
ii). Transferring knowledge by taking part in training centres in Africa; and
iii). Product development for improved water supplies and sanitation.

WBG strives to be a reliable water partner for industry, local and regional authorities. For example, through North Water WBG supply custom-made solutions to industry, WBG design, build, finance and maintain water installations. Via RioNoord and together with the Hunze en Aa's and the Noorderzijlvest Water Boards (WBG) assist local authorities in the field of sewage management. Via Water Laboratorium Noord (WLN), WBG provides technological research and consultancy services to commercial organizations such as Heineken and Philips and checks the quality of drinking and industrial water.

WBG is continuously searching for new opportunities to utilize and enrich its expertise. It strives for sustainable cooperation with its clients, and considers dependability, reliability of supply and transparency to be key issues. In addition, WBG looks to strengthen further the organization by entering into strategic alliances with other parties such as industrial companies, research and educational institutions, government authorities, environmental organizations and nature and wildlife organizations. In addition to RioNoord, North Water and WLN, WBG has formed an alliance with eight water companies in Germany under the name '**Ems-partners**'.

WBG focus on the future will lead to investments that will further strengthen both the utility role and market oriented activities. This could include investments in the purification and recycling of industrial wastewater, in sewage management or in energy supplies to residential areas, using ground source heating and cooling systems. As a public company, WBG tries to contribute positively to the future of the different regions. WBG term this as waterpower, the power of WBG.

Lessons learned:

i). Many of the Dutch water utilities services, such as customer relations and repairs, are contracted out to the private sector.

ii). Guidelines are in use for undertaking work near underground assets under the Utility Providers Code of Practice, utilities such as road, rail, inland waterway networks, motorways of the sea, seaports and inland waterway ports, airports and other interconnection points between modal networks.

iii). Benchmarking: An interesting feature of the Dutch water sector is a performance benchmarking system for water companies amongst ten regional water companies. Initially, the benchmarking was undertaken to forestall a government proposal by the Ministry of Economic Affairs to establish a regulatory agency based on the British model. The Dutch benchmarking exercise covers four areas: water quality, service, environment, and finance and efficiency. The Dutch benchmarking programme was the first nationwide benchmarking exercise in the water supply sector in continental Europe.

iv). Efficiency: Using established indicators for the technical operational efficiency of water utilities, the Dutch water companies are highly efficient. For example, according to the association of Dutch water utilities, leakage losses are below 6%. According to the same source, the number of employees per 1,000 connections (water only, without sanitation) is less than one. Both these figures are among the lowest in the world.

3.4 National Water and Sewerage Corporation (NWSC) Uganda

The National Water and Sewerage Corporation was initially established by Decree No. 34 of 1972. In 1995, the Corporation was re-established by the National Water and Sewerage Corporation Act, with the primary aim of revising the objectives, powers and structure of the Corporation and to enable the Corporation operate on a commercial and viable basis. The NWSC is a public Corporation entirely owned by the Government of Uganda. The principal business of the Corporation, as defined in the National Water and Sewerage Corporation Act, is to operate and provide water and sewerage services in areas

entrusted to it under the Water Act. The National Water and Sewerage Corporation currently operates in 23 towns, namely Kampala, Jinja-Njeru, Entebbe, Tororo, Mbale, Masaka, Mbarara, Gulu, Lira, Fort Portal, Kasese, Kabale, Arua, Bushenyi-Ishaka, Soroti, Lugazi, Iganga, Malaba, Mukono, Hoima, Masindi, Mubende and Kaberamaido. NWSC serves a population of 3.4 million people in the large urban centres of Uganda, with water service coverage of 76 per cent by June 2012 (NWSC, 2012)

Asset Management Process development

There are no authorized and systematic processes for managing and replacing the corporation assets. Lack of a comprehensive asset replacement policy affects the implementation of internal inventory control procedures, asset management processes and general tracking of assets. In addition, the corporation lacks complete, accurate financial audit capabilities for technology assets required by the Business & Finance Division, Internal Audit, or third-party auditors (NWSC, 2012).

NWSC is on the roadmap to introduce asset management. Currently, staff in the maintenance division are undertaking training to be certified as asset management practitioners under PAS 55. There are indications that there is an effort towards asset management and a greater understanding of assets and transparency of risk through awareness creation, improved information on performance and condition, and an integrated company-wide approach to business processes and learning. Improvements on decisions on asset interventions are aimed at increasing levels of certainty about both the resilience of current service and the ability to deliver expected future needs.

The company structure, conventionally arranged around maintenance and operations, is being changed to one that focuses on optimizing the management of assets. The Asset Management and Efficiency theme has two major goals. The first is a comprehensive asset management system established through improved maintenance of fixed assets, updated asset register, functional GIS system, updated investment plan, financial model and improved working capital. The second goal is that the expected improved working capital will be as a result of improved debt management, improved inventory efficiency and improved creditor management (NWSC Corporate Strategy, 2012).

Lessons learned

NWSC proposes a Comprehensive Asset Management System that will result from improved maintenance of fixed assets, updated asset register, functional GIS system and an updated investment plan and financial model. The following key indicators will measure these results:

i). Maintenance costs as *a* percentage of operating costs

ii). NRW from 32.6% to 30.1%

iii). Approved Asset Management Policy

iv). Water supply reliability throughout the day and week

v). Unbundle up to level 4 all assets acquired since 2007; and

vi). Add at least 10 more towns on GIS platform in additional to KW updated one.

3.5 Cases in Sub-Saharan Africa

This study also examined other case studies in Sub-Saharan Africa including Lusaka Water & Sanitation Corporation, Zambia; Kisumu Water & Sewerage Company Ltd (KIWASCO), Kenya; Nairobi City Water & Sewerage Company (NCWSC), Kenya; and Johannesburg Water (SOC) Ltd, South Africa. During an asset management workshop that these utilities attended, they provided information of the different levels they had attained with regard to the roadmap towards introducing asset management, tools and techniques, situational analysis, stakeholders, major contributions and challenges. The utilities highlighted initiatives at the highest level and steps to the development of the policy and legislation towards ensuring that asset management becomes a legal requirement for all water services providers. They also indicated prospects for innovation techniques for infrastructure risk assessment; decision-making techniques for capital investments; studies on the implementation of asset management in utility practice, and the use of GIS and IT technology. Other improvements include the various techniques of meter replacement, pressure management, continuous leak detection and rehabilitation of infrastructure.

Input captured from the preceding findings was incorporated in the study. Broad-based improvements in applied asset management practices provide for a huge step toward bringing about sustainable systems. The workshop also revealed that strategic asset management is growing and will shape how water utilities provide water services in the future.

3.6 Decision-making Practices in Asset Management within Water Utilities

The author set out to establish the decision-making practices on assets at NWSC, WBG and RW. The exploration enabled retention of a limited number of critical practices for each category of assets per case study. Table 3-1 presents the decision-making practices in the three water utilities.

Table 3-1: Decision-making practices across case studies

	DECISION-MAKING PRACTICES ACROSS THE CASE STUDIES		
ASSETS	**NWSC**	**WBG**	**RW**
Buildings and Property Civil Structures	• Meetings on a daily basis – operational field meetings. • Proactive inspections to develop intervention plans • Planned schedules • ISO Certification (ISO Standard 9001:2008) • Maintenance (Condition based , Predictive , Planned, Corrective & Preventive) • Audit • Quality Management • Painting schedules, • Calibration	• Meetings • Monitoring program • Annual inspection round • Regular schedule every 5 years maintenance – painting • PAS 55 customized for WBG company • Maintenance program (short and long terms plans; preventive plans) • Maps • Schedules • Visual inspections	• Meetings on a monthly basis; inter-station meetings with the field. • Maintenance (Condition assessment; RCM) • Management by Walking around (Engineers go round and talk to site employees on the problems experienced without following a formal methodology) • Main streaming policy priorities/ policy compliance (Procedures derived from Policies) • Certification (ISO) • Institutionalizing AM (has been informally applied in RW).
Pipelines and Servitudes	• Maintenance (Condition based, Predictive, Planned, Corrective & Preventive) • Schedules, checks • Audit • ISO Standards followed	• Maintenance (Quality, Curative, Preventive) • Digital system to register installations and soil type (i.e. acidic, nice sand, clay) over pipelines • Flashing pipelines to clean them is part of the	• Maximo – gives you a single point of control over all types of assets by managing them all on a common platform. This platform allows sharing and enforcement of best practices, inventory, resources and personnel.

	DECISION-MAKING PRACTICES ACROSS THE CASE STUDIES		
ASSETS	**NWSC**	**WBG**	**RW**
		routine schedule • Replacement is on annual basis • Inspections, pressure tests • Investment program, • Control extraction points and shutdown – control crane to shut down pipes due to leakage • OBIS to monitor age, incidents, ground structure requirements • Modelling system for pipelines	• High-level inspection using radars/flying over the pipeline, detectors, etc. • ISO standards (Risk department) cleaning of pipelines – scouring and flashing of the pipes done under ISO 9000 • Procedures • OEM - Original Equipment Manual is followed - captured into the system and done accordingly for pumps, pipelines, treatment plants; anything that affects the organization to supply water follows the above.
Electrical Equipment	• Maintenance (Planned Preventive, Predictive, Corrective, Condition based) • Condition monitoring • Planned schedules	• Guideline ten-ten • Every 3 year inspection • Thermo graphic imaging • Project basis, replacement based on age • Annual inventory • Emergency power supply – weekly, inspection/test schedule for short breaks • Outsourced to contractors • NEN3140 general approach to maintain electrical equipment and for safety • OBIS to collect data and analysis • Failure Modes Effects and Criticality Analysis (FMECA) • Maintenance (Preventive, Curative, schedules, lubrication, every 5-10 years, vibration power analysis)	• Meetings on a monthly basis – inter station meetings with the field. • Condition assessment • Maintenance schedule i.e. 3 months, 6 months • Certification • Registering all assets on the asset register – know the assets • Procedures
Mechanical Equipment	• Routine schedules	• Visual inspection	• Lots of information and

	DECISION-MAKING PRACTICES ACROSS THE CASE STUDIES		
ASSETS	**NWSC**	**WBG**	**RW**
	• Maintenance (Planned Preventive, Predictive, Corrective, Condition based)	• Vibration measurement (OBIS) • Maintenance (Preventive, Curative, schedules, lubrication, every 5-10 years, vibration power analysis) • FMECA – maintenance program, routing system to schedule work • OBIS to collect data and analysis	decisions were not talking to each other – target is to integrate one point of entry. • Maintenance schedule • ISO Certification • Reliability centred tests • Every 8000 runs pumps are tested • Historical Asset Management being formalizing • Procedures • Proactive strategies – identifying what should be done to prevent asset failure. • Preventive Maintenance (PM) Schedule, i.e. 3 months, 6 months, uploaded into the system, printed once a week by the maintenance division and maintenance according to plan is done for all assets
Process Plants	• Maintenance (Planned Preventive, Predictive, Corrective, Condition based)	• Water quality analysis • Long term analysis – project trends – 5 years • Process reviews • Renovation project • Maintenance (Preventive/curative) annual inspection and control • Analysis of quality of water • FMECA – maintenance program, routing system to schedule work • OBIS & technology centre WLN (Water Laboratory North)	• Intranet assists in view assets guided by the map, instant information, planning – communicate with site and come up with requirements i.e. replace, refurbish, repair, dispose etc. • Maintenance schedule i.e. 3 months, 6 months • ISO Certification • Business Process Re-engineering conducted in 2008 – mapped out business process that are supporting Asset Management • Every 5 years, i.e. distribution network, there is a procedure for cleaning reservoirs. RW does not necessarily wait for the 5 years if there is no compliance the reservoir will be cleaned under ISO 9000 • Root Cause Analysis – not only for corrective action but

	DECISION-MAKING PRACTICES ACROSS THE CASE STUDIES		
ASSETS	**NWSC**	**WBG**	**RW**
			also for preventive maintenance.
Automation Equipment	• Maintenance (Planned Preventive, Predictive, Proactive, Corrective, Condition based) • Monitoring and Evaluation • Temperature control • Accessibility control • Various checks • PPM schedule	• Every 3 years replace server • PLC and equipment replaced 10-15 years • Follow manufacturers manual • Software and POC – communication • Maintenance (preventive and curative every year inspect and control) • Outsourcing • Department GIGA responsible for automation • Preventive monitoring of wells & quality of water • Technical knowledge to define the scope • Outsource - many of the services, e.g., customer relations and repairs, are outsourced. • OBIS • FMECA	• Reflect on the system for condition assessment • Maintenance schedule i.e. 3 months, 6 months • ISO Certification • Inspection schedules • Procedures • Proactive strategies – identifying what should be done to prevent asset failure.

In order to establish the challenges that hinder effective water asset management, interviews were conducted with staff and management at the three water utilities. The results from the interviews revealed the following key challenges:

i). Lack of adequate policy on asset management

ii). Limited funds for water asset management

iii). Lack of political will/management commitment

iv). Lack of awareness by staff about water asset management

v). Poor coordination and planning

vi). Poor communication and negative attitude to maintenance management

vii). Lack of adequate soft and hardware skills to undertake water asset management

viii). Lack of information on condition of assets

ix). Lack of decision-making and collaboration capabilities.

3.7 What decisions in Water Utilities should be enhanced?

The respondents were asked to mention the decisions that can be supported by the Decision Enhancement Studio for Water Asset Management and the following were underscored:

i). Decisions on maintenance, rehabilitation, and replacement (asset management);

ii). Decisions on investment planning to inform prioritization, especially depending on the scope (short-term and medium-term for replacement/refurbishment in the areas of tactical/operational levels); and

iii). Decisions on risk management that inform the decisions on asset management and investment planning.

Decision activities related to Maintenance, Rehabilitation, and Replacement

A utility collecting accurate data about their assets provides a better understanding of their maintenance, rehabilitation, and replacement needs and thus assist utility managers make better monitoring programmes and maintenance schedules. Among the challenges of asset maintenance, utilities cited a lack of condition assessment and limited use of formal methods for asset maintenance. Within maintenance, management decisions on asset renewal can improve the reliability and performance of infrastructure. Decisions for timely renewal of assets support reliability, availability and maximum utilization of infrastructure and enable business continuity. Reliability of assets influences significantly the quality of life and provides a stable foundation for economic growth and competitiveness (Pudney, 2010). Failures of assets lead to an interruption in service delivery and generate customer complaints, which affect the goodwill of the utility and the customers' willingness to pay for the service. Utilities need support in the midst of challenges to implement asset management including collecting and managing needed data and making the organizational cultural changes necessary to integrate information and decision-making across departments (GAO, 2004). Water utilities can benefit from asset management including improved decisions making on their capital assets and more productive relationships with governing authorities, ratepayers, etc.

Decision activities on Investment Planning

Utilities need support to make better investment decisions by helping them identify needs and plan future investments through facilitative environments. This would in turn help them to support meetings and make them more productive and engender constructive engagements among stakeholders. The challenges cited about meetings included; lack of participation from stakeholders, lack of consensus, lack of commitment, lengthy meetings and absenteeism.

Decision Making Activities on Risk Management

Risk management is a key input in decision making activities on maintenance, rehabilitation, replacement and investment planning. Because many of the water utility assets (pipelines) are buried, water utilities have had difficulty applying risk management techniques (Aikman & Doherty, 2006). This obscures the utility's ability to analyse the condition of the assets or assess failure. This is demonstrated by the challenges utilities experience in quantifying and evaluating the risk posed by potential failure of an asset. Water utilities need to identify operating and maintenance procedures and capital rehabilitation or replacement projects to lessen the risks of possible failure (Aikman & Doherty, 2006). One utility cited high insurance costs after a major burst of a water pipeline that resulted in a whole village being evacuated. Another utility mentioned the negative publicity that was covered by media houses over a major burst that gave the utility major setbacks.

In summary, decision-making in the water domain can be characterized as a complex and wicked problem (Head & Alford, 2013). In the next section, the author explores the functional requirements regarding the studio design.

3.8 Requirements for the DES-WAM

The author set out to establish the characteristics of a decision enhancement studio enhancing water asset management. To accomplish this, the respondents in the three water utilities were asked to identify the desired characteristics for an ideal DES-WAM design which is a wicked problem with unstable requirements and constraints (Hevner, 2008); the stakeholders generated many requirements. However, we chose to focus on

requirements that directly lead to solving the problem specified in Section 1.3. The following were the suggestions made by the respondents:

i). The solution should provide stakeholders with an environment to share information.
ii). The solution should enhance collaboration, interaction, and communication among stakeholders to promote positive attitudes to maintenance as well as increase effort in and budget for water asset management.
iii). The solution should allow customers to report incidents and in turn get feedback on maintenance works.
iv). The solution should facilitate improvement in decision analysis for asset maintenance, risk management and investment decisions by providing scripts to guide water asset management decisions.
v). The solution should enhance collective participation of all stakeholders without fear of victimization.
vi). The solution should provide a means of sharing information about decisions made through secure deployment.
vii). The solution should be of low cost.

The findings indicate that there is a need for an adaptable solution that enables analysis of decision alternatives as well as collaboration and constructive dialogue, in the complex and dynamic water asset management domain. Decisions about the way assets are managed are of utmost importance in ensuring effective asset maintenance. This research therefore proposes a decision enhancement studio that can enhance decisions. In the next chapter, the author provides design of the proposed decision enhancement environment for water asset management.

CHAPTER 4
DES-WAM STUDIO DESIGN

This chapter explains the design of the WAM studio for enhancing decisions based on requirements. This builds on the asset management decisions presented in Chapter 2 and refined with the exploratory case studies in chapter 3. In section 4.1, the author presents the design approach based on Sol's "ways of" framework. Section 4.2 addresses the way of thinking. Section 4.3 sets forth the way of governance. Section 4.4 demonstrates the way of working while Section 4.5 illustrates the way of modelling.

4.1 Design Approach

The underpinnings that guide the design hinge on seven principles for inquiry systems (Gonzalez and Sol, 2012), namely the purpose is creating knowledge; the measure of its performance is societal; the client is humankind; and knowledge should go outward to be useful for the entire society. Others include; the inquiry system needs a cooperative environment; the decision-makers ideally involve everyone; and the designers are ideally everyone. In addition, the assertions of the inquiry system are stated in "ought" form as an imperative rather than "is". These principles guide the design of a suite of software tools in a studio to support sector managers in management, documentation, collaboration and communication, training and visualization in their decision-making processes. The main purpose was to enhance decision-making in asset management by creating knowledge jointly on risks reports, complaint logs, investment plans and decisions to rehabilitate, repair and replace assets for life-cycle delivery. Therefore, basing on the asset management decisions presented in Chapter 2 and the exploratory case studies in chapter 3, the following were the design considerations for the DES-WAM:

i). The design should enable efficient and effective (Frolov et al., 2010) complaints handling of customer/public complaints to prolong asset life (Hastings, 2010) and cut back on response time to asset failure incidents leading to the scoping and costing of engineering interventions (Lloyd, 2012).

ii). The design should support stakeholders at different levels, tactical and operational levels (CIEAM, 2008; Amadi-Echendu et al., 2007; Wittwer et al., 2002), for accountability (Mohammadi, 2011; Bhagwan, 2009) and flexibility (Keen & Sol,

2008) in handling both management and maintenance issues. More so in ensuring that an appropriate mix of interdisciplinary skills can be accommodated in resolving the complex issues in asset management (Amadi-Echendu et al., 2010). This is so because all levels must commit to asset management in order for it to be successful especially in planning at the strategic level and implementation at the operational level (Bhagwan, 2009; Van de Honert et al., 2013).

iii). The design should facilitate communication and commitment between management and maintenance staff in implementing asset management (ISO 55002, 2014; Lloyd, 2012; Transition guide, 2014).

iv). The design should facilitate methods, tools and a technique in an environment that supports collaboration so that the stakeholders in charge would make decisions faster (Lloyd, 2012). The purpose in collaboration was to greatly amplify and accelerate individual and team thinking effectiveness. Most information systems utilized by the water utility industry fall short of implementing systems that deal with asset management decisions (Mathew et al., 2006).

v). The design should provide guidelines (Hastings, 2010; Nunamaker et al., 1991; Transition guide, 2014) of using the participatory studio to build consensus, agreement and commitment during decision-making in asset maintenance (Keen & Sol, 2008).

The DES-WAM overview shown in figure 4-1 consists of technology suites, stakeholders, asset management decision process areas and factors affecting the way assets are managed.

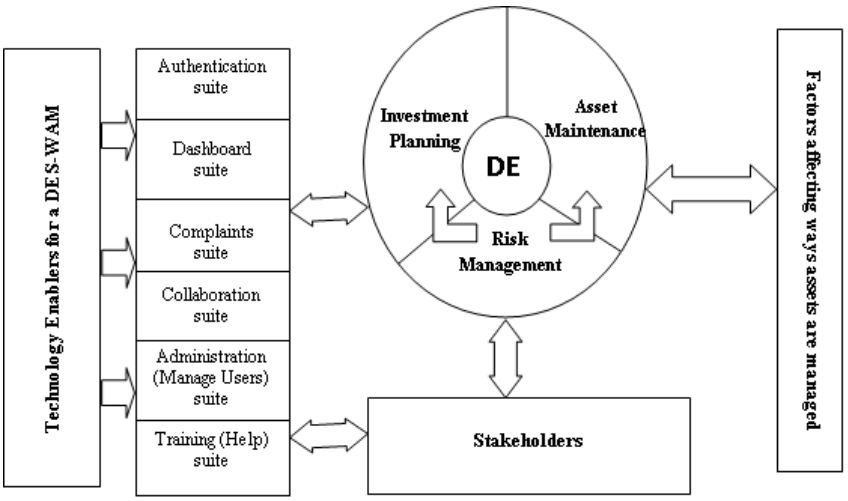

Figure 4-1: DES-WAM overview

***Note**: Decisions on asset maintenance involves asset maintenance, rehabilitation, replacement and renewal.*

The DES-WAM consists of six suites of different technology enablers, namely the authentication, dashboard, complaints, collaboration, Administration (Manage Users), and Training (Help) suites. In addition, as part of the DES-WAM, facilitation, guidelines and scripts are provided to support stakeholders (e.g. sector managers, engineers, and customers, public) involved in the asset management decision-making process. The major decision areas of the asset management decision process include decisions on asset maintenance; decisions on investment planning; and decisions on risk management. In making decisions during asset management, factors affecting the way assets are managed in water utilities are also taken into consideration (see Figure 4-1). These factors may include but are not limited to existing policies, governance, culture, regulatory bodies, operating and ownership structures, customer service requirements, socio economic factors, political factors, economic factors, environmental factors, technology and business objectives (Pudney, 2010).

In the DES-WAM, stakeholders should thus be able to use the available suites (technology enablers) to make decisions with regard to asset maintenance, investment

planning and risk management, considering the various influencing factors. Moreover, risk management decisions are considered when making asset maintenance and investment planning decisions. These suites, the supporting guidelines and scripts subsequently enhance the asset management decision process, by facilitating management, documentation, collaboration and communication, training and visualization. Participatory studios are much more invitational and aim at encouraging the involvement of participants in the process that is most likely to lead to consensus, agreement and commitment.

The design is discussed in terms of the way of thinking, way of governance, way of modelling and way of working following Sol's analytical framework (Seligmann *et al*., 1989) and shown in Figure 4-2. This framework is based on the experience of several researchers in information systems (Amiyo, 2012; De Vreede and Briggs, 2005;) who were able to successfully employ the framework in the design, development and implementation of information systems, approaches, methods, frameworks and solutions to problems in various domains.

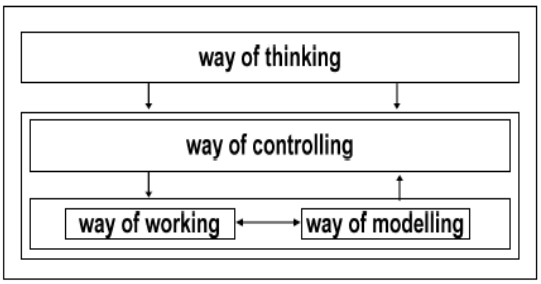

Figure 4-2: Framework to consider design approaches (Source: Sol, 1988)

4.2 Way of Thinking

The *way of thinking* depicts the concepts and theoretical foundations to enhance decisions for water asset management (WAM) as well as expressing the underlying philosophy. In order to address the decision-making challenges in water asset management, a decision enhancement studio for water asset management was designed. The design focused on a

participatory studio that is invitational and aims at encouraging the involvement of participants in the decision processes to arrive at a consensus (Keen & Sol, 2008).

A studio provides a common reference point for structuring WAM decision processes using appropriate technology and involving different actors. Three major perspectives for WAM decision enhancement stand on an interaction of people, process and technology.

The "*people*" aspect refers to the actors involved in the water asset management decision processes. People make decisions which are shaped by their institutional knowledge, skills, values, judgement and experience (Keen & Sol, 2008). Participants are stakeholders when they are involved in the decision-making. These stakeholders are actors in the studio and include administrators, sector managers, engineers, the public, government, security agencies, customers and their roles in the water asset management decision processes (Table 4-1).

The decision "*process"* influences the likelihood of actors to make effective decisions. Flexibility is a key element of decision enhancement studios. Flexibility can be described as the degree to which decision enhancement studios are able to adapt to changing circumstances (Gosain, Malhotra & El Sawy, 2004). The decision enhancement services as modular building blocks enable flexibility in complex and dynamic decision-making contexts (Knol, 2013). The modular decision enhancement services allow loosely coupled deployment to adapt to changing circumstances when needed (Gosain, Malhotra & El Sawy, 2004; Weick, 1976).

The "*technology"* enables decisions by providing the tools necessary to realize water asset management packed in suites, guidelines and a facilitative environment.

Table 4-1: Actors in the DES-WAM

Actors	Roles	Example
Administrator	• Guide sessions: In-charge of setting up and running the sessions in the studio • Invite participants: responsible for invitations to meetings and assigning credentials • Adds feedback to incidents reported	• Chauffeur – person to act as a driver to decision processes, i.e, guide brainstorm, categorize, vote, reach consensus and commitment.

Actors	Roles	Example
	• Ensure that the studio works and delivers the relevant services	
Sector Managers	• To participate in studio activities such as brainstorm, categorize, vote & evaluate decisions • Receive evaluation report with key decisions	• Sector managers: - • Strategic level- Long-term planning • Tactical level - Managerial
Engineers	• To request for complaints log, track and resolve complaints while giving managers key inputs for further decisions • To make updates on issues resolved and those pending	• Operational level - fire fighters in the thick of everything
The Public	• Utilities cannot manage the fight against NRW on their own and hence the public reports and informs the utility of what is wrong.	• Community policing to report vandalism, water theft, bursts and leakages for a timely response.
Government	• Government can come up with policies to support water utilities control NRW including massive campaigns to create awareness to reduce NRW.	• Government can put up campaigns to sensitize communities on asset maintence and business continuity when the water pipeline network is well maintained.
Security Agencies	• These agencies could report the problems of meter vandalism in the system and illegal connections and handle crimes relating to water issues.	• Security agencies can police communties for water pipe vandalism and illegal connections
Customers	• Consumers are able to detect water leakages/bursts early and report to the utility thereby aiding response time and cutting back on NRW, a benefit for all stakeholders.	• Customer's complaints/failure rate information diffused from social media into the studio (i.e. face book/text messages/pictures)

Technology provides multiple types and levels of support focused on enhancing asset management processes (Keen & Sol, 2008). Water asset management decision process needs to be skilfully handled and designed; not reliant on high tech, but should appear like hand-drawn studio by a skilled illustrator. However it is generated by a PC, displayed and updated on a screen; this makes the studio more invitational, natural and easy to relate to (Keen & Sol, 2008).

4.3 Way of Modeling

The way of modelling identifies the models that were used for decision-making (Van de Kar, 2004; Sol, 1982). In modelling, diagramming techniques were used as the initial

grammar for representation and visualization (Pinkwart, 2008). In the way of modelling the DES-WAM, was the most important to capture the dynamic (operating) behaviour that characterizes the water asset management decision-making process. To represent this dynamic behaviour, UML (Unified Modelling Language) was employed to model how the decisions are made using DES-WAM. The two main UML diagrams used were the use case and activity diagrams. The DES-WAM use case (Figure 4-3) depicts how the different suites in the DES-WAM interact for decisions to be made in water asset management. The activity diagrams on the other hand, model the activities that are supported by each suite in the DES-WAM.

4.4 Way of Governance

The *way of governance* expresses the managerial aspects of the artefact in use. The way of governance describes measures and methods for managing water assets decision processes (Sol, 1988). Below the author examines issues that should be observed while considering supporting decision-makers in a multi-actor environment.

Actors with ample time and commitment should be involved. Preparation is crucial in the DES-WAM studio and participants need to put aside time and treat this as an important factor for improving decision processes for water asset management.

All levels of management, namely strategic, tactical and operational levels, should be encouraged to participate in the DES-WAM decision processes for the results to be usable and useful. In working collaboratively, better decisions for water asset management are realized and by engaging all levels of management in decision processes, a greater level of commitment is achieved.

Actors involved in the DES-WAM should have the required skills. These actors will all benefit from prior training to have a meaningful participation in the deliberations. Participants should have an appreciation of asset management backed with exposure, skills and the dynamics surrounding water asset management. Those using the instrument should have the necessary experience and skills. This will lead to involvement and commitment in the decision processes as well as improvements in water asset management. Flexibility is important in water asset management given the intricate

issues involved; therefore, the DES-WAM supports a flexible environment where actors can be guided to deliberate on different issues using scripts. The studio environment supports effective use of time and space, as well as ensuring the flexibility of receiving messages to advance sector managers' efficiency in responding to incidents.

Variations in viewpoints are also supported in the studio and the categorization tool enables participants to group ideas and then vote on those themes they wish to optimize. The participants following a discussion select the themes that they consider key to asset management. The different levels of management involved normally generate several decision alternatives. Managers gain and share more insight through sector managers who set their own theme.

Feedback is provided during the collaboration meeting using discussion rooms where all can see anonymous submissions provided by participants. An evaluation report is provided at the end of the meeting for communication and record purposes and in case more insight is required on an issue, a manager can request for a follow-up meeting. Feedback plays an important role in learning and decision-making. It helps to create a coordinated setting for multi-actor interaction (De Bruijn et al., 2002).

Adaptive strategies are appropriate for the DES-WAM given the different actors involved (Sol & Crosslin, 1992). In this strategy, a design process is regarded as an adaptive process of learning for the actors involved in solving the water asset management issues.

4.5 Way of working

The way of working denotes the steps that are followed in using the water asset management studio for decision enhancement. Based on the challenges and observations, the proposed studio suites and functional requirements are presented in Table 4-2. According to Keen & Sol (2008), a suite of software services is the foundation for meshing technology and the process. It contains domain specific information and communication services, which form building blocks and support recipes for repeatable processes.

Table 4-2: DES-WAM suites and their functions

DES-WAM suite	DES-WAM functionalities and requirements
Dashboard • Complaints allotment • Complaints log • Communication log	• Facilitate data capture/inserting information in the system: • Textual and non-textual information • Enable display of information in the system
Complaints Suite • Visualization of incidents reported • Display of information in charts • Manage customer complaints • Label complaints as per status • Give feedback on action taken	• Visualization: the decision-makers should be able to identify in which zone or specific area an incident is by showing it on a map. • Fast information: when there is an incident, it should be known as fast as possible to alert the decision-makers to take action via social media and crowd sourcing. • The studio can be deployed for crowd sourcing • Customer complaints diffused from social media to gather incidents data into the studio for management decision. • Enable an application on the mobile phone for customers to report incidents and in turn get feedback on action taken. • The same application can be a tool to empower customers to protect water assets by using it to report asset vandalism and water theft.
Collaboration Suite • Create a meeting - enter meeting information (title, start time, estimated duration), meeting agenda and invite attendees • Manage entire decision process (brainstorm, rank, rate and quest) • Report is automatically generated of meeting process and action planning on next steps. • All the above activities should take place within the specified period set by the moderator while creating a meeting. Once the time is up the session closes automatically.	• Enhance collaboration, interaction and communication among the stakeholders. • Stakeholders have to collaborate using the studio to resolve reported incidents for asset maintenance, investment planning and risk management. • Facilitate improvements in decision analysis and decision-making skills for asset management by providing scripts to guide decision processes - brainstorm, rank, rate and quest. • Enhance the collective participation and commitment of management and public where applicable to decisions in water assets. • Provide a means of sharing knowledge and information about water assets and decisions made through secure deployment: • Meeting invitations are sent out via SMS and/or email. At the meeting time, attendees navigate Collaboration Suite to view a list of meetings and join the appropriate ones. • Provide facilitation scripts to create a predictable pattern of collaboration on decision-making • Create repeatable processes that provide structure and can be run by stakeholders • Attendees are presented with a page where they can anonymously contribute their ideas to the meeting and view others' ideas.
Administration (Manage Users) suite • Create user	• Access authentication: • Generation or editing of data shall be restricted to staff: where public input is desired through social media, these

DES-WAM suite	DES-WAM functionalities and requirements
• Controlled access to the studio • Reports generated but access defined by category	shall be subjected to validation by staff before being considered as input. • Various types of reports shall be generated but access to them shall be defined by category of access.
Training (Help page) • Knowledge base module for e-learning on asset management • Guidelines to use the studio	• Enable training using e-learning for stakeholders working as asset managers to be able to: i). Use the studio approach through guidelines (recipes) to understand and deploy new asset management concepts in the work environment ii). Target management activities associated with asset maintenance, investment planning and risk management. iii). Results should raise revenue and ensure that assets continue to provide value throughout the asset lifecycle at minimum cost of ownership and are consistent with commercial and risk management strategies.

Subsequent to the way of thinking described in Section 4.2, and considering the derived requirements in Chapter 3, six suites were identified to provide the required functionality of the studio. The six suites are authentication, dashboard visualization, complaints, collaboration, administration (manage users) and the training (help) suites.

In the Dashboard suite, the DES-WAM supports sector managers (strategic, tactical and operational levels) to keep track of asset related parameters, complaints and other issues that pertain to water assets. A dashboard is a visual display of the most important information. It is an easy to read real-time user interface, screening a graphical presentation of the situation and trends on an organization key performance indicators to enable informed decisions to be made quickly (Marchesani, 2014). It also supports sector managers in following up on asset complaints raised and resolving issues in a timely and cost effective manner. During the exploratory studies, a manager in Waterbedrijf, Groningen intimated that complaints are treated as gifts to the company because they tell the company what it is not doing well.

A computer dashboard with a customized map of a region can be of use to sector managers irrespective of location to make decisions regarding maintenance, investment planning or risk management (see Figures 5-3 and 5-4). Using the dashboard managers

can assign repair jobs to engineers with prior knowledge, for example, on right equipment. It is also feasible to make a daily schedule for repairs to optimize the amount of work done on a daily basis. Sector managers can use this dashboard to prepare for maintenance work using information and/or pictures of the incidents.

Models used in the DES-WAM

The models used in the DES-WAM were designed using the Unified Modelling Language (UML). UML is a notation (mainly diagrammatic) for modelling systems using object-oriented concepts (Larman, 1998). In addition, UML is a language for specifying, visualizing and constructing the artefacts of software systems (Booch et al., 1999). Given the many possible DES-WAM activities from requirements through to implementation, the author employed UML because it supports the prototype development process describing the possible order of activities that help in understanding the problem and requirements by stakeholders.

Activity diagrams

Activity diagrams are graphical representations of workflows of stepwise activities and actions with support for choice, iteration and concurrency (Booch et al., 1999). In the Unified Modelling Language, activity diagrams are intended to model both computational and organizational processes (i.e. workflows). In the DES-WAM, activity diagrams were employed to model decision processes.

Use case model

Use cases describe processes. They are a useful preliminary step in describing the requirements of a system. Understanding the DES-WAM requirements includes, partly understanding the water asset management domain processes.. In the DES-WAM, the use case begins when a customer or the public report an incident i.e. pipe burst, water leakage, or stolen meter among others.

A use case diagram has been used to envision the actors/stakeholders and their roles in the DES-WAM (Figure 4-3). The actors/stakeholders include sector managers, engineers,

public, customers and administrators who influence asset management decisions. Bittner (2002) states that use cases, allow one to describe the sequences of events which, when taken together, improves the usefulness of a system. The use case diagram provides a powerful way to express the behaviour of the DES-WAM in a way in which all the actors/stakeholders in the water utilities can easily understand.

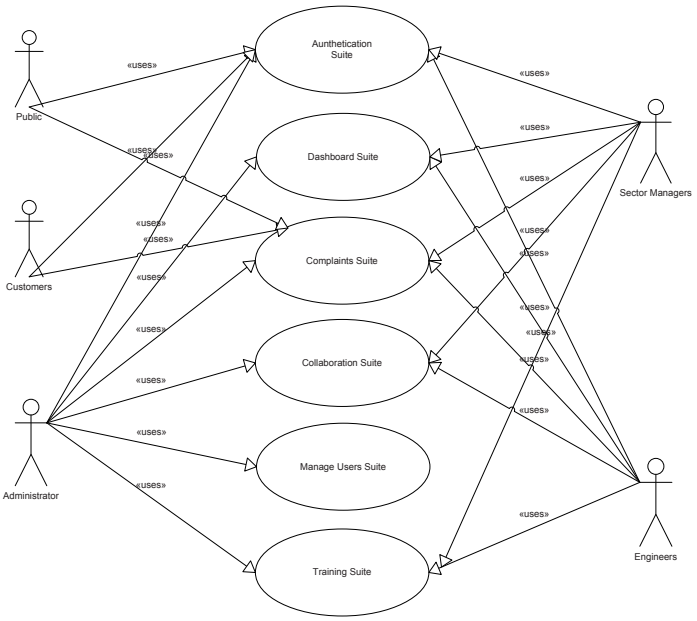

Figure 4-3: DES-WAM Use case Diagram

Access to the studio is defined based on the various roles performed relating to data and information on asset maintenance. Generation or editing of data is restricted to staff of the utility through access authentication: where public input is desired through social media. These are subjected to validation by staff before they are considered as inputs as shown in Figure 4-4.

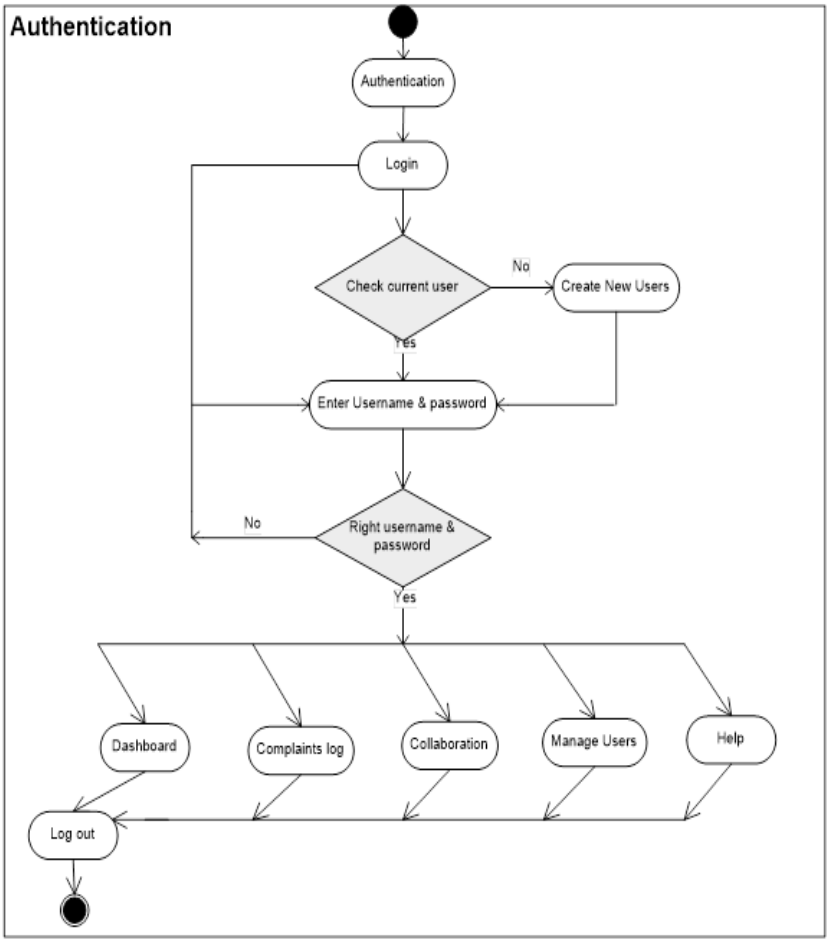

Figure 4-4: Activity diagram showing authentication for accessing DES-WAM Dashboard suite

The DES-WAM provides visual thinking by providing a platform where incidents are mapped on Google maps for sector managers to see how the pipe network is doing. The water asset management studio helps actors in keeping track of asset related parameters, complaints and other issues that pertain to water assets. The dashboard creates a meeting of minds through sharing of sights and insights – visualization. This visualization obviously is a distinct value in helping sector managers articulate what the issues are in water asset management. Comparisons and interpretations by sector managers are via visualization. The evidence is strong that visualization is at the very core of human

decision-making. The DES-WAM is built with communication capabilities, development tools and visualization aids to support decision-makers in asset management. Enhancement rests far more on images that are most consequential, complex, and uncertain, and a shift from the design of computer- and telecommunications-based tools to a far more comprehensive 'studio' approach to the integration of dynamic visualization and communicative display (Keen & Sol, 2008). DE enables shared visualization amongst stakeholders. DE enhances the link between people and technology in new ways, particularly through the DE focus on visualization. The DE axiom, "if you can't see it, you won't get it" enables the studio to have inbuilt tools that help people get it (Keen & Sol, 2008). Below is Figure 4.5, an activity diagram illustrating dashboard visualization in the WAM studio.

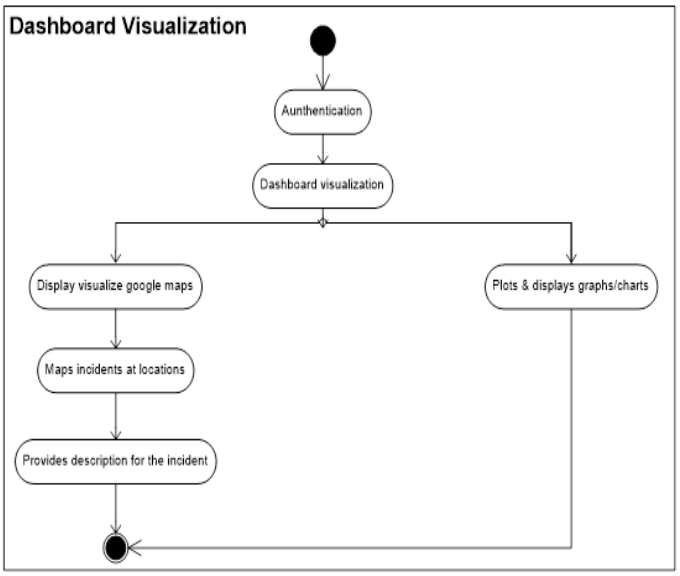

Figure 4- 5: Activity diagram showing the dashboard suite

Complaints suite

The water asset management studio aids actors in keeping track of asset complaints raised and resolving them in a timely and cost effective manner. Asset related issues (incidents) are reported via social networks (Facebook, Twitter, and SMS) and an Android mobile application. Incidents with positioning information are logged on a map where the administrator can easily view additional detail about the incident. The DE

studio and suite design has been made in such a way as to encourage involvement. Active and meaningful stakeholder involvement right at the outset is the goal. If there is any lack of appropriate involvement then usability questions arise. Complaints management is complex to build and requires far more participation and skills by the strategic, tactical and operational levels. Figure 4-6 provides an illustration of an activity diagram of the complaints suite.

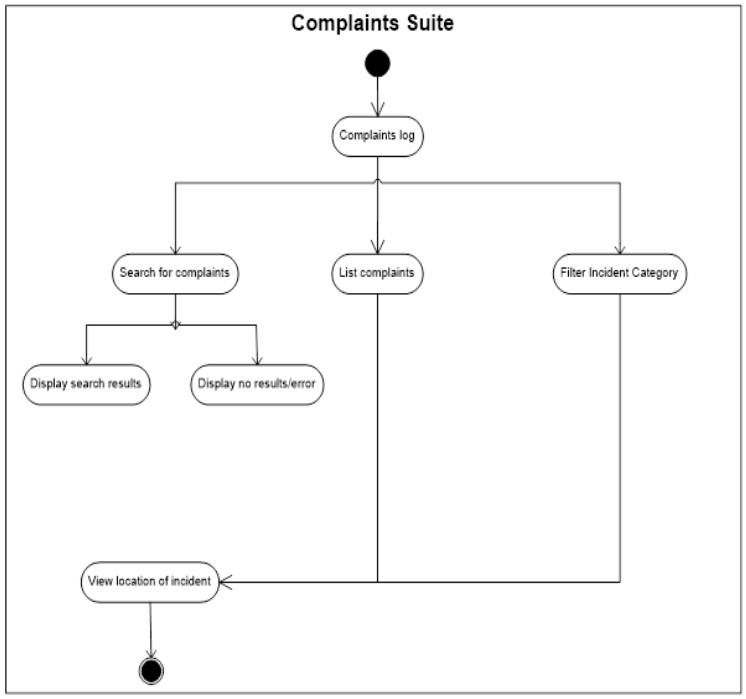

Figure 4- 6: An Activity diagram of the complaints suite

Collaboration suite

Decision Enhancement substantially adds to the opportunities, especially in the use of Internet as an information resource and a communication base for collaboration between sector managers.

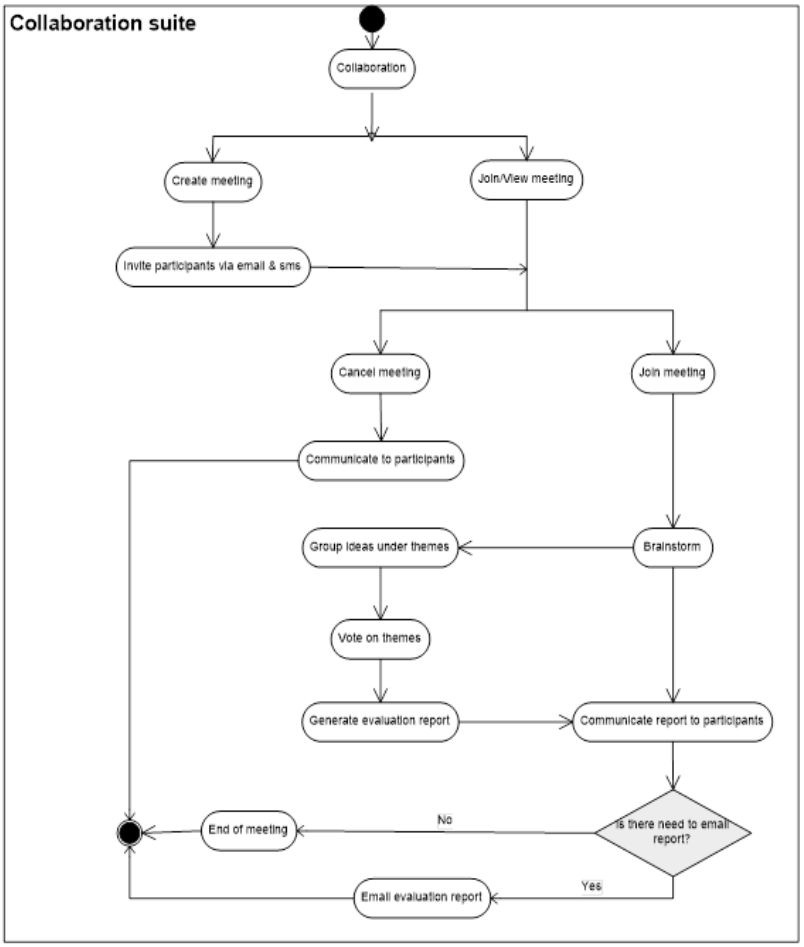

Figure 4-7: An Activity Diagram of the collaboration suite

The internet opens up new multi-media opportunities to decision enhancement: from PC to network, from face-to-face decision-making group to networks of actors, real-time and using visualization tools. Of paramount importance are decisions on asset maintenance; when to repair, refurbish and replace an asset as well as issues to do with investment planning and risk management. Figure 4-7 provides an illustration on the collaboration meeting in an activity diagram.

At the meeting, the administrator will present the document to the audience, explaining the methods and findings. The administrator is responsible for fielding questions from the audience and presenting them in a non-threatening way. In addition to leading the meeting, the administrator takes notes of issues that still remain in order to be distributed and re-analysed later.

Managing user's suite

Security is a primary requirement for the studio, access to the portal and all data (Keen & Sol, 2008). The more the links and the more the parties involved, the more difficult it is to balance access and control. Communication and security, hence the studios have been built with managing user's in mind to be able to control access. Water utilities have sensitive information that does not need to go out to the public and managers are entrusted with an executive task of making decisions on behalf of the public; therefore, deliberations need protection. Figure 4-8 illustrates the Administration (Manage Users) suite process in an activity diagram.

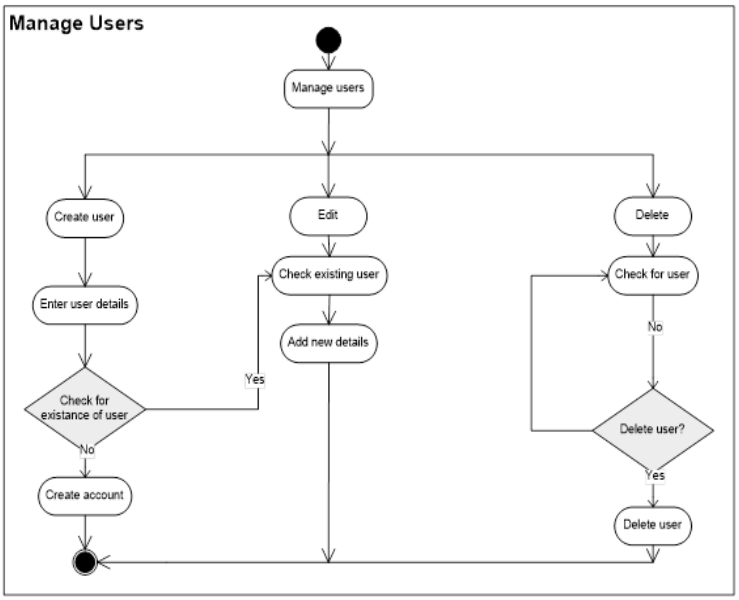

Figure 4- 8: An Activity Diagram showing the Administration (Manage Users) suite

Training suite

The Training suite is seen as core to Decision Enhancement studios (Keen & Sol, 2008). The training mode provides a knowledge base on asset management to support stakeholders and gain a common understanding of issues pertaining to water asset management. Most companies invest in leadership training to boost productivity. In turn, the sector managers will be better able to participate in the improvements required for decision processes in asset management. They will then be able to understand the collaboration meeting presented to them by the studio and make informed decisions about water asset management. People's behaviour is changed through training. Learning studios become vehicles for training (Keen & Sol, 2008). Training is transferring information to organization members to positively improve the effectiveness and productivity of organizations (Ssemaluulu, 2012). Training enables organizations to act more effectively because of having valued employees (Mehrabani & Mohamad, 2011). Skills are crucial and most companies have employed training programmes to build teams and facilitate change and leadership (Keen & Sol, 2008). The training suite is adapted to get managers/users acquainted with the DES-WAM prototype and understand what constitutes water asset management and how decision processes can be improved.

In the next chapter, we discuss the implementation of the solution and examine the different cases DES-WAM prototype was tested on.

CHAPTER 5
IMPLEMENTATION OF DES-WAM

This chapter describes methods and techniques for implementing the DES-WAM studio prototype. The chapter contains excerpts from Chapter 3, which explore the asset management environments in the water utilities. Implementation of the DES-WAM studio prototype is based on the exploration and studio design phases with the aim of providing a solution to asset management decision challenges. Construction of the DES-WAM studio prototype is founded on survey and literature review. The solution is tested in three case studies, namely Nairobi City Water and Sewerage Company, Kenya (NCWSC); Kisumu Water and Sanitation Company, Kenya (KIWASCO); and National Water and Sewerage Corporation, Uganda (NWSC). Section 5.1 gives the WAM studio prototype description, and Section 5.2 presents the implementation considerations. Section 5.3 gives the DES-WAM instantiation while 5.4 provides the designing of test sessions for the studio.

5.1 Implementation considerations

At the beginning of the exploratory study, requirements were accentuated (see section 3.8) and brought out in the development of the Decision Enhancement Studio for Water Asset Management (DES-WAM) presented in Chapter 4. To verify the DES-WAM design, an instantiation of the studio was developed to check its functionality. In implementing the DES-WAM instance, a number of issues were considered at the studio level.

Studio Level

At the studio level, implementation considerations were made on issues relating to organizational decision-making and how to facilitate stakeholders/ users to work together collaboratively in their important roles while factoring in change management and leadership (Carpenter, 1990; Mathew et al., 2006; Lloyd, 2012). This is because exploration studies had provided information on what should be captured while designing and implementing the studio. In the technology area, the focus was on interactive suites

with an amalgamation of multi-media interfaces, visualization tools, architectures, the Internet and data integration (Keen & Sol, 2008).

Suite Level

At the Suite level, HTML5 was used, JavaScript for the client side and PHP/MySQL/Apache for the server side. PHP was the preferred option for this project because of the following reasons:

i). It is widely supported by 98 per cent of the web hosting services support PHP and PHP add-on modules.

ii). It works well with HTML5. PHP was used to extend the capability of plain HTML5 and improve the overall experience of the studio.

iii). It has improved performance and security. Later versions of PHP have improved security and language performance features.

iv). MySQL is an open source database system that was built with reliability, security and performance in mind. Client complaints and other information are saved in a MySQL database for easy retrieval and advanced manipulation of the data, for example, data mining.

The Apache web server is a leading web-server that works well with open source technologies whose functionality can be extended using add-on modules and hence its use in studio development and implementation.

Mobile Application

An off-the-shelf Android Application was used to crowd source complaints from clients/ end users via social media, SMS and other channels (Figure 5-1). The author focused on creating insight capability through the data aggregated and utilized to create insight in the location, incident type and complaints which enables effective decision-making in asset maintenance. Hear-Me-Out (www.hearmeout.me) is an Android based application that enables clients send structured queries to the water service providers.

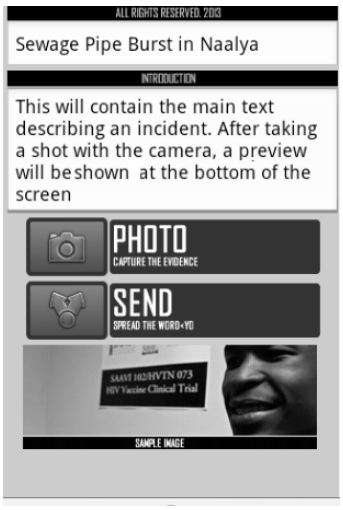

Figure 5-1: Screen shot of Mobile Application showing how to report a complaint

Social Media Integration

The respective social media platforms expose methods and mechanisms with which third party applications can connect and make use of the data therein. Facebook SDK and Twitter API were used to interface with the respective social media accounts.

Database

The MySQL database engine was used to store and retrieve data from clients, client complaints and meetings. The following tables were used to store and manipulate data:

i). ***Client***: This table keeps track of clients' information i.e., name, phone, email, location.

ii). ***Client Complaint***: The table keeps track of client reported fault reports, leakages, pipe bursts and other related concerns.

iii). ***Client Complaint Response***: The table keeps track of responses to queries, whether they were resolved or not, and how they were resolved.

iv). ***Meeting:*** With time, the incident reports paint a picture of what is happening. This data is visualized on a map and can be deliberated on by top management. The meeting table keeps track of planned meetings.

v). ***Meeting Agenda***: This table keeps track of meeting agenda i.e. modifications, additions, or other changes.

vi). ***Meeting Attendee***: This table keeps track of who attended the meeting.

vii). ***Meeting Minutes***: This table keeps track of issues discussed during the meetings.

Natural Language Processing (NLP)

NLP techniques were used to make sense of unstructured queries and assign them to the respective persons. Apache OpenNLP was used for tokenisation, sentence segmentation, part of speech tagging, named entity extraction, chunking, and parsing.

5.2 DES-WAM Prototype

DES-WAM is a core component of an interconnected information system providing an environment for a participatory approach that would lead to consensus, agreement and commitment to decisions as recommended by Keen & Sol (2008). To foster this environment, it would necessitate working with the right information from the sector managers and stakeholders when and where it is needed.

To ensure that all user requirements had been captured, an initial paper-based prototype was developed with four suites. This was presented to stakeholders to aid in the reflection and discussion of requirements to see that their interests were satisfied. From the complete set of requirements, the design presented in chapter 4 was developed and this formed the basis for the DES-WAM (computerized) prototype presented in this chapter.

The DES-WAM prototype is a studio with facilitation guidelines, on the "how to" of coming up with solutions in water asset management, with an aim to greatly amplify and accelerate individual and team thinking effectiveness. Therefore, the facilitation guidelines are presented as scripts for innovation to be used by stakeholders during collaboration sessions in the studio. The DES-WAM Prototype consists of six suites, namely the authentication, dashboard visualization, complaints, collaboration,

administration (manage users') and the training (help) suites to support collaboration, flexibility and dynamism in decision-making.

Authentication is an important aspect of computer security (Clarke & Furnell, 2007). Therefore, in the DES-WAM, the Authentication Suite provides a means of sharing information about decisions made through a secure deployment. Dashboards as well as data in these dashboards are accessed via a robust role-based access control mode. As such only authorized users can access the specific dashboards.

The Dashboard Visualization Suite displays a real time feed of issues being reported laid out on a map interface. Enhancement rests mainly on images, dynamic visualization and communicative display (Keen & Sol, 2008). Visualization tools are needed to inform while at the same time they accelerate better understanding. Visualization is therefore important in productivity (Singh, 2013).

The Complaints Suite manages the studio complaints process from reporting to assigning engineers to the job and eventually labelling it as 'solved'. Clients send in complaints via an Android application, Facebook, SMS or Twitter. The responsible managers can then make decisions in resolving the pending issues.

In the Collaboration Suite, management can easily brainstorm ideas on how to solve pressing issues. These could be trends identified from the logged complaints or other issues that are deemed important. A supervisor schedules a meeting, sends out email invites and proceeds to host the meeting virtually. Here the use of the Internet is both an information resource and communications base as suggested by Keen & Sol (2008).

In the Administration (Manage User's) Suite, the module limits user access and functionality with ease. It further keeps meetings private and notifies concerned parties when there is a breach. In the Training Suite, a sustainable approach was developed for providing training for people in management to enhance decision-making through business intelligence systems to find the right ideas, solutions or answers through the studio environment. The Help module within the Training Suite provides guidelines on how to use the studio and a knowledge base on asset management basics.

5.3 The DES-WAM

A DES-WAM instantiation was developed by building an interface to link the suites to provide an environment in which stakeholders/ users are supported in the WAM decision process (Figure 5-3). Through the dashboard interface, stakeholders access the DES-WAM enabling them to enhance decisions in asset management among other things.

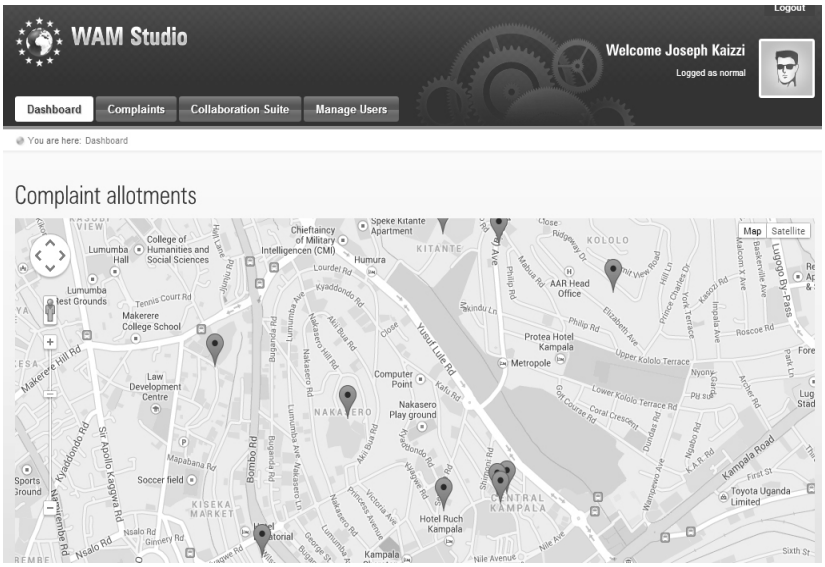

Figure 5-2: Screen shot of dashboard visualizing crowd sourced Incidents on a Map

The water asset management studio aids in keeping track of asset related parameters, complaints and other issues that pertain to water assets. It also aids in keeping track of asset complaints raised while resolving them in a timely and cost effective manner.

Asset related issues (incidents) are reported via social networks (Facebook, Twitter, and SMS) and an Android mobile application. Incidents with positioning information are logged on a map (Figure 5-3) where the administrator can easily view additional details about the incident (Figure 5-4).

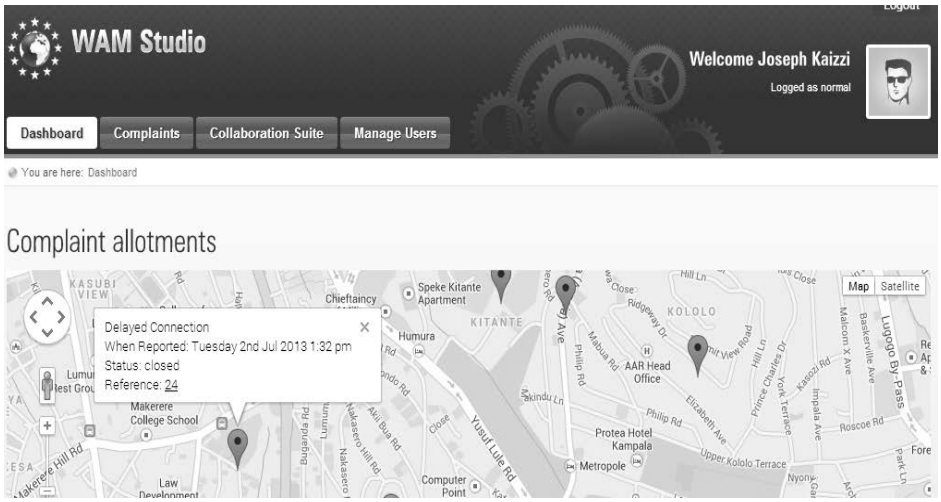

Figure 5-3: Screen shot showing an Incident Summary

Clicking the reference number under any particular incident will reveal additional details about the incident (Figure 5-5). Staff with the appropriate rights can then modify the query i.e. add a response or label it as resolved. The reporting party is automatically notified when there is a modification to their query.

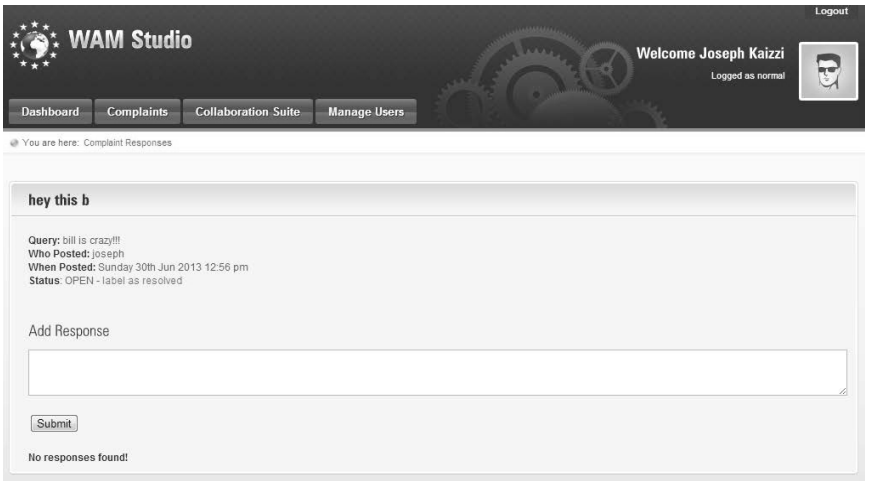

Figure 5-4: Administrator adds feedback to incident reported

Labelling a query as resolved means that either the reporting party is satisfied with the action taken or they went silent. No further action can be taken after an incident is closed. If the problem persists, a new incident will have to be reported. A communication log showing exchange between the administrator and the reporting party can be viewed right below the incident response page (Figure 5-6).

Communication Log

Navigating to Complaints >> Complaints Log: will show a list of all incidents that have been reported. One can filter by reporting party, incident category, location and others. One can also search through an incident log. The green highlights indicate incidents that have been resolved while the red highlights indicate incidents that are pending or yet to be resolved (Figure 5-6).

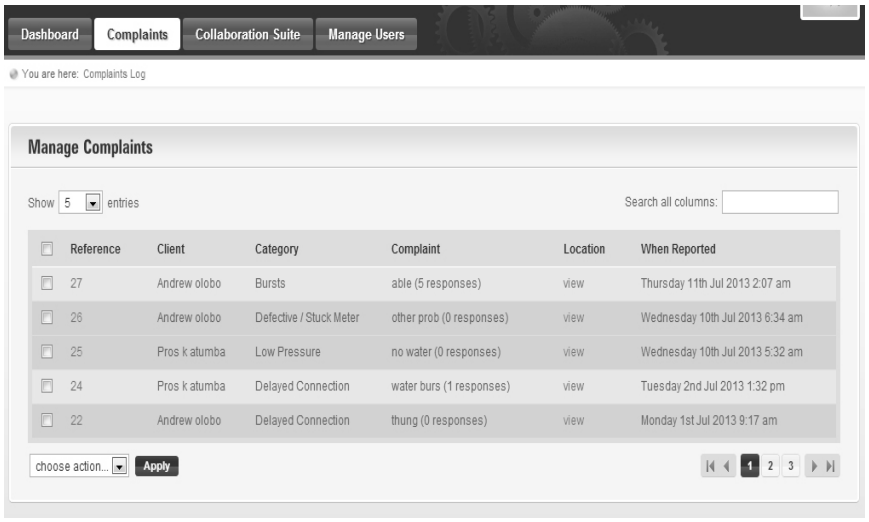

Figure 5- 5: Complaints Log

Navigating to Complaints >> statistics: will show us a visualization of incidents reported over different periods. Bar charts, line graphs, area and pie charts exist. This helps in visualization, giving a sense of what is happening (Figure 5-7). The asset incident reports and other statistics help to provide management with the necessary information they need to make asset-based decisions.

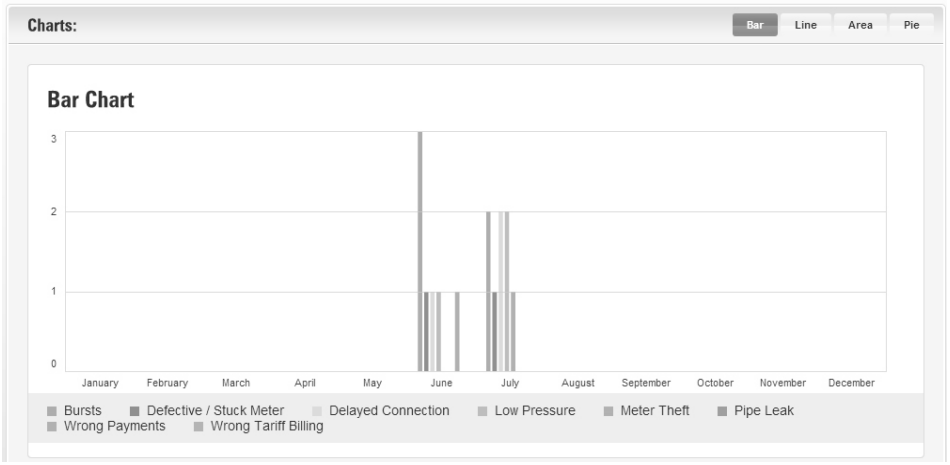

Figure 5-6: Visualization Example

The author has included a module that will ease collaboration between decision-makers and provide a framework through which they can easily arrive at concrete decisions

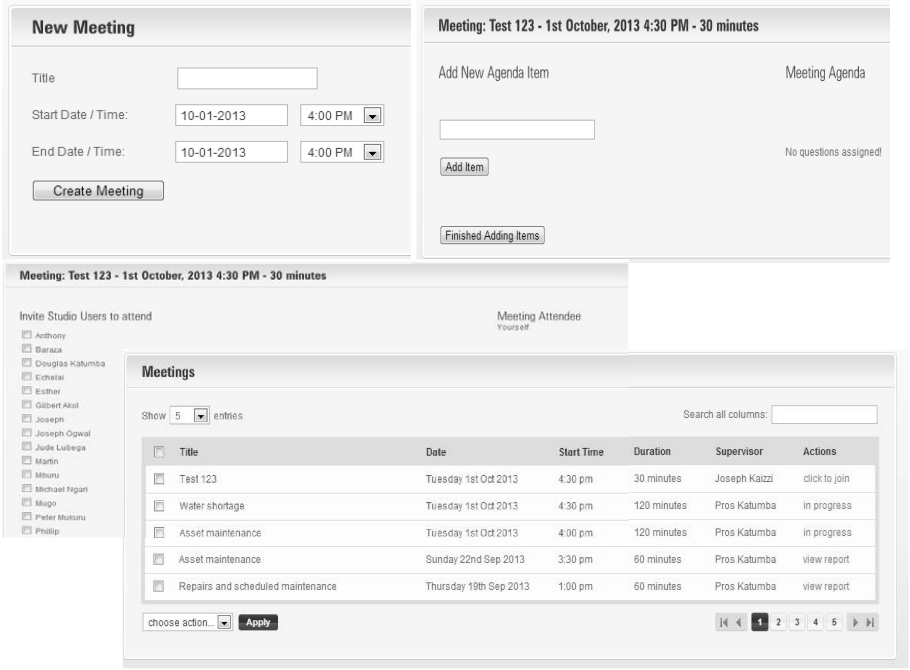

Figure 5-7: Screen Shoots showing the collaboration suite

Staff or other personnel in charge navigates to Collaboration Suite >> New meeting. To create a meeting, s/he then follows the different prompts: entering meeting information (title, start time, estimated duration), meeting agenda and inviting attendees (Figure 5-8).

Invitations are sent out via SMS and email. At the time of the meeting, attendees navigate to the Collaboration Suite to view a list of meetings and join the appropriate ones (Figure 5-8: meetings). Attendees are then presented with a page where they can anonymously contribute their ideas to the meeting and view others' ideas. The meeting administrator (the one that created the meeting) has additional options available to them, for example, inviting additional attendees during the meeting, managing the entire meeting process (grouping of ideas, voting, and action planning) as shown in Figure 5-9 Meeting objectives can be activated at different times to guide the attendees in the right direction.

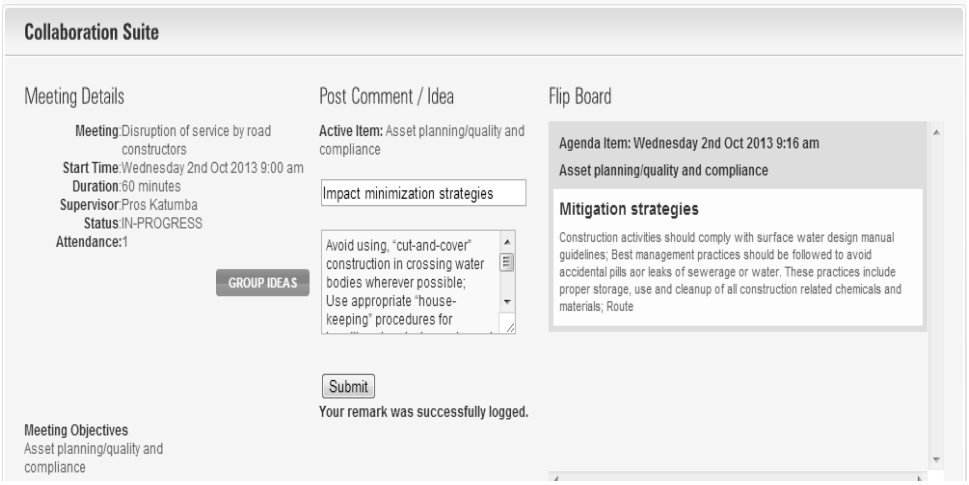

Figure 5-8: Screen shot showing Meeting details, Comment Posting and Discussion rooms

After collaboration, the moderator then proceeds to group similar ideas (Figure 5-10)

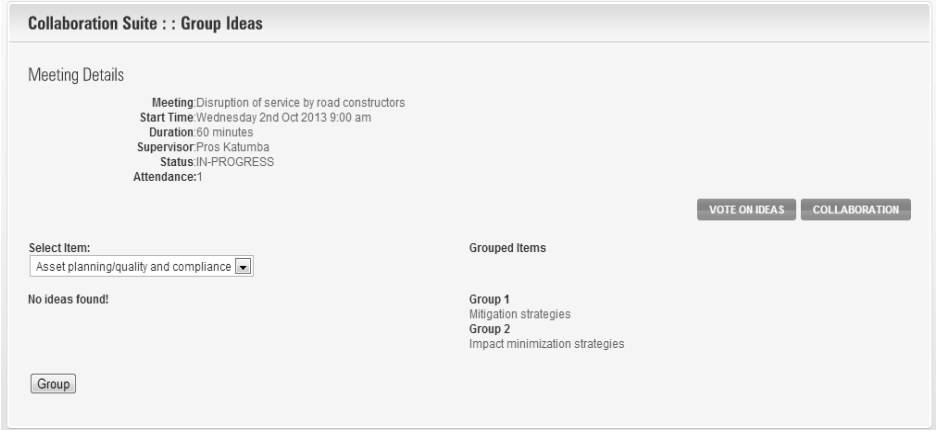

Figure 5-9: Screen shot showing Grouping of ideas

After the voting process, the results are then presented to the attendees. An action plan is then developed based on the voting result.

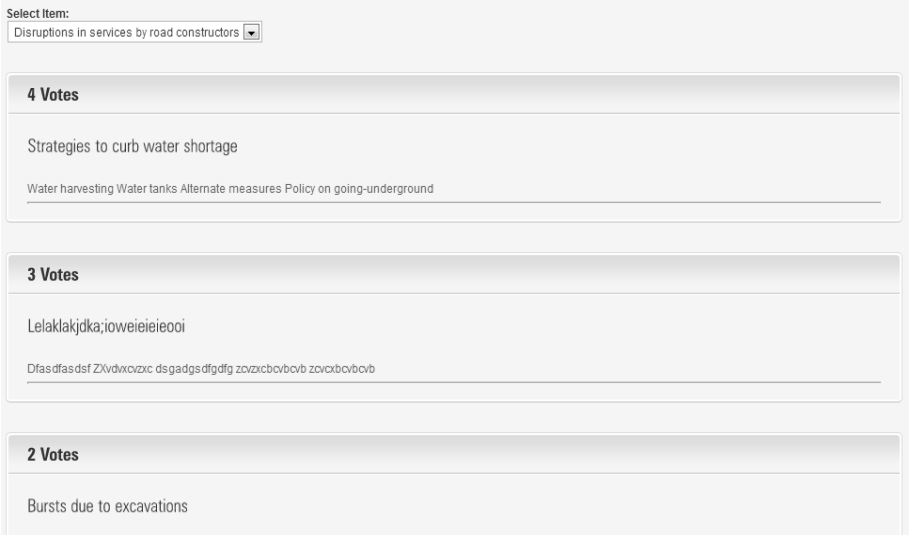

Figure 5-10 : Screen shot showing the Voting Results

Attendees are then presented with a report detailing the entire process, deliberations and voting, and recommendations on next steps based on the voting process (Figure 5-12).

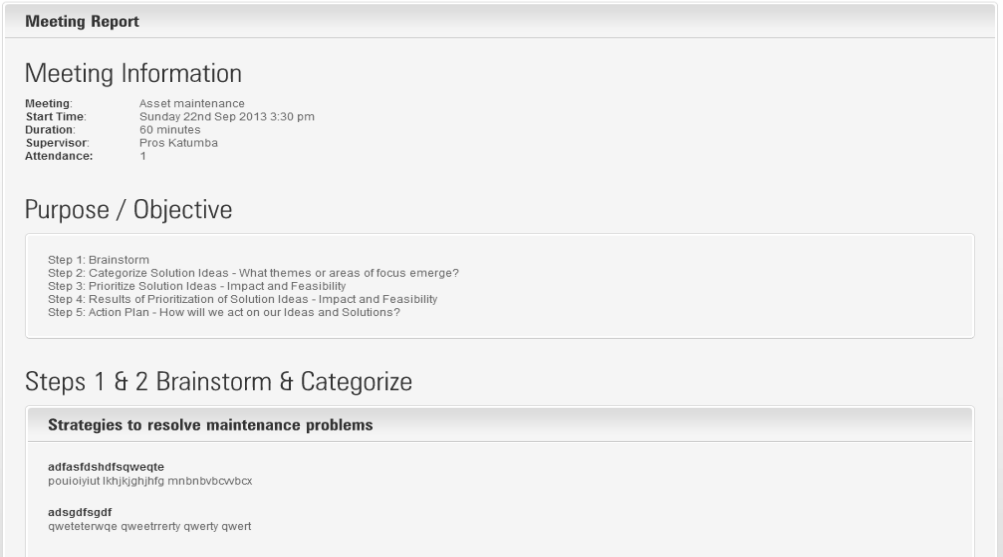

Figure 5-11: Meeting Report

All the above activities happen within the specified period set by the administrator when creating the meeting (Figure 5-12).

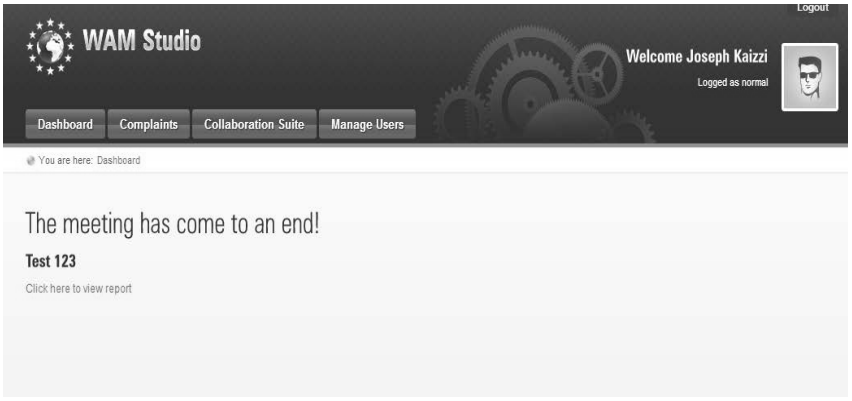

Figure 5-12: Screen shot showing the end of scheduled meeting

5.4 Test Sessions for the DES-WAM

The test sessions were carried out at Nairobi City Water & Sewerage Corporation, Kenya (NCWSC), Kisumu Water & Sewerage Company, Kenya (KIWASCO), and National Water and Sewerage Corporation Uganda, (NWSC). These water companies were selected and willing to participate in the study because they had taken part in the Asset

Management Workshop organized at Rand Water, Johannesburg in South Africa in January 2013.

Insights from Nunamaker et al., (1991) informed the Guidelines and Scripts for running collaboration sessions in the DES-WAM described in Table 5-1.

Table 5-1: Showing Collaboration Session Guidelines and Script

Guidelines	Script
1. Present the studio design and the guidelines that are followed during the group session for the case study, including two issues to run sessions in the studio deployment, i.e., a. Determining the best time to rehabilitate and replace aging assets; and b. Responding to emergencies as a result of asset failures	1. Explain the methods of testing the studio: Walkthrough sessions are conducted as informal methods for the studio testing. A walkthrough is a schedule meeting with the author in charge of the prototype. 2. Explain the roles of the various participants: administrator, chauffer, coordinator, and the participants 3. Explain the next steps: a. Participants gather up any questions or concerns b. After the testing, the administrator will present findings to the participants c. The administrator takes note of issues that remain in order to be re-analysed later.
2. Participants start brainstorming on the two issues identified to run sessions one at a time. Each item on the list links to the discussion room. Each participant goes through the topics to contribute as dictated by interest and expertise.	1. Explain the topics to the group and verity that the participants understand them. 2. Explain the kind of ideas that the group must contribute 3. Explain how to post to the flip chart. 4. Say this: a. Start working on the topics in which you have the most interest or the most expertise. Then, if one has time, move on to the other topics to read and comment on the contributions of others. b. You may not have time to work on every topic, so work first on the topics that are most important to you.
3. Reduce and move from many concepts to fewer concepts by filtering or abstracting. 4. Bring concepts to the discussion room during a plenary discussion. Help people create shared understanding regarding their own key issues.	1. Say this: a. We have extensively elaborated on the issues at hand and created many comments. Let us now zero in on the key ones and discuss them together. b. I like you to go through the comments and pin an annotation to comments that you feel are key that ignited your interest, made you think, changed your perception on the issues at hand, or those that best summarise a number of other comments. c. The content of the annotation itself is not important; just make sure a "pin" appears in the margin of the comment. d. You may only add (X) annotations 2. The group reads the comments and places their annotation pins. 3. If the group is done placing their annotation pins, invite them: "Please skim through the comments and check out the ones that are "pinned". We will discuss these together in a few moments." 4. After the group has placed their annotation pins and read the highlighted comments, facilitate an oral discussion

Guidelines	Script
	during which you invite people to explain why they felt certain comments were key.
5. Create an understanding of the relationships among the concepts. Participants browse their brainstorming comments and pick items that are related. 6. They articulate the relationship between the two items, and if the group agrees, the relationship becomes the name of a category.	1. Say this: Please read the comments on your screen. If you find that two or more comments are related in some way, tell me how they are related. 2. Add a new bucket (category) with the relationship as a label. 3. Continue the process until participants can find no more relationships.
7. Focus a discussion on a judgment of the work of a set of concepts with respect to a goal that needs to be attained. Then enable the group to make sense of the insights. Take into consideration the preferences of the group and the level of consensus among participants.	1. Say this: a. We are going to evaluate. We are not making a final decision right now. We just want to get a sense of the group to be able to focus our subsequent efforts. b. I have sent you a ballot containing a set of X items. c. Please rate each item on a scale of Y to Z. d. The Y-rating means… e. The Z-rating means… f. When you finish rating, click the "submit ballot" button that appears just above the ballot on the left
8. Track patterns of consensus on a single issue in real time. Move from having fewer to having more people who are willing to commit to a proposal by arriving at a mutually acceptable agreement. 9. If the participants hear something that changes their opinion while talking, they change their vote. 10. Make a decision. 11. Update results in real time.	1. Say this: a. Please register your opinion in the discussion room. b. Now let us talk about the issue. If you hear anything that changes your mind in either direction, shift your vote accordingly. We will keep talking until we have reached some sort of consensus on this issue.

Nairobi City Water & Sewerage Company (NCWSC)

The Company's headquarter offices is situated along Kampala Road in Nairobi's Industrial Area. The Company has six regional centres: NCWSC is a water service provider (WSP) to the City of Nairobi and its environs under a license issued by Athi Water Service Board (AWSB). NCWSC is 100% owned subsidiary of City Council of Nairobi (CCN). The company's area of operation has a population estimated at 3.6 million (KNBS 2009). It is estimated that 99.9% of the water supplied to the city is

surface water, the rest is ground water. Most of the water comes from Aberdare catchment.

DES-WAM Set Up

Administrator:	Researcher
Chauffeur:	Research Assistant
Coordinators:	Manager Engineering Services and Manager Non-Revenue Water Department
Equipment:	Laptops for each participant connected to the Internet
Sitting arrangement:	Semi-circle
Participants:	4-5 people per session
Phase 1:	Training session participants on how to use the studio
Duration:	10-15 minutes
Phase 2:	Hands on experience by the participants in using the studio
Duration:	45 minutes

Permission to test the DES-WAM studio prototype was sought and granted through telephone conversations and email communications with managers at NCWSC. A meeting was held with the participants. Three groups were organized in separate test sessions based on three levels, namely the operational, tactical and strategic levels. This was done because participants who manage the decision processes and staff who actually do the fire fighting would gain both high-level and low-level perspectives on management issues and how to resolve them. Ideally each session had about 4-5 people who would consult, collaborate and come up with solutions to management and maintenance issues.

The researcher began with training to provide guidelines on how to use the studio and provide a knowledge base on asset management basics. The administrator scheduled meetings, sent out email invites and proceeded to host the meeting virtually. Participants were assigned passwords to use the studio and authentication was ensured. The Dashboard displayed a real time feed of issues being reported laid out on a map interface and this enabled visualization of reported incidents. The complaints suite enabled

participants to view how the studio manages the complaints process, from reporting to assigning staff to the job and eventually labelling it as solved. Customers would send in complaints via an Android application, Facebook, SMS and Twitter. The responsible managers would then make decisions in resolving the pending issues.

During the collaboration meeting in the studio, the administrator worked with these teams on a few issues such as decisions on determining the best (optimal) time to rehabilitate/replace ageing assets and the other issue was responding to emergencies as a result of asset failures. While the Administration (Manage Users) suite enabled setting limits between user access and functionality with ease, it kept meetings private and notified concerned parties when there was a breach. The Internet was not stable and this was a challenge to the participants.

After interacting with the suites, the participants concluded that the DES-WAM enabled real time collaboration on water asset management. In addition, it supported complaints capture and presentation of the situation analysis on the pipe network. More so, the DES-WAM enabled consolidation of data from the different reporting avenues such as Facebook, Twitter, SMS onto one dashboard for easy decision-making.

Kisumu Water & Sewerage Company Limited (KIWASCO)

KIWASCO started autonomous operations in July 2003 after taking over from the Water Department of Kisumu Municipal Council following the enactment of the Water Act of 2002. KIWASCO has two water treatment plants with a capacity of 45,600m3/day and two waste water treatment plants whose total capacity is 17,800m3/day. About 60% of Kisumu residents get their water from KIWASCO directly or through established water kiosks. About 40% of the population get their water from boreholes and shallow wells among others.

DES-WAM Set Up

Administrator: Researcher
Chauffeur: Research Assistant

Coordinators:	Head of Technical Services
Equipment:	Laptops for each participant connected to the Internet
Sitting arrangement:	Semi-circle
Participants:	6-7 people per session
Phase 1:	Training session participants on how to use the studio
Duration:	10-15 minutes
Phase 2:	Hands on experience by the participants in using the studio
Duration:	45 minutes

Permission to test the DES-WAM studio prototype was sought and granted through telephone conversations and email communications with administrators at KIWASCO. A preparatory meeting was held with the participants and the researcher to organise test sessions at the operational, tactical and strategic levels. Although it was preferred to have about 4-5 people per session, this was not possible. Some sessions comprised more participants (6-7). The participants were hosted in the studio for consultation, collaboration and coming up with solutions to management issues. These sessions were quite interactive and noisy because of the big numbers. The Internet was on and off and some participants lacked laptops.

In the wake of applying all the suites, the participants concluded that DES WAM studio had visual features that could clearly display and analyse information concerning incident reporting for decision-making. The collaboration suite brings managers into a virtual world where they can hold meetings wherever they are; hence, an organisation can take decisions quickly and cut back on response time to reported incidents. Those multi-communication methods employed in organizing meetings such as email and short messages alerts (SMS) and tracking who is still in the meeting can reduce absenteeism at meetings. People at different management levels of the organization would benefit from the DES-WAM studio by having an input on decisions made. Some plates were taken during field-testing of the DES-WAM at KIWASCO with the operational and tactical level participants (Plates 1 & 2).

Plate 5-1: DES-WAM testing operational level employees at KIWASCO

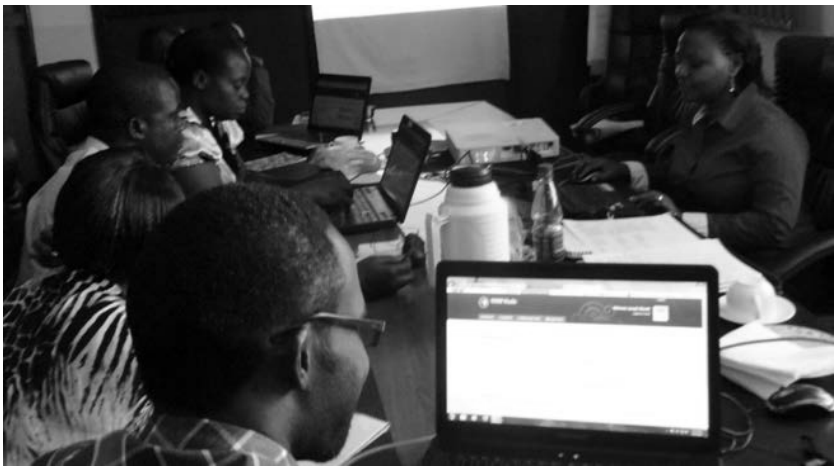

Plate 5-2: DES-WAM testing tactical level employees at KIWASCO

National Water and Sewerage Corporation (NWSC)

NWSC is a Ugandan parastatal and set up in 1972 and started with three charter Towns of Kampala, Entebbe and Jinja). Under the Water and NWSC Statutes of 1995; Acts Cap.152 & 317, NWSC is mandated to provide water, sewerage, sanitation services (WSSS) in large urban centres on a commercial and viable basis. Currently, the company serves a population of about 4 million people and has 297,041 customers in 23 major towns (NWSC Report, 2012).

DES-WAM Set Up

Administrator:	Researcher
Coordinators:	GIS Manager
Equipment:	Laptops for each expert connected to the Internet
Sitting arrangement:	Semi-circle
Participants:	3 people per session
Phase 1:	Training session on how to use the studio
Duration:	10-15 minutes

Permission to test the DES-WAM studio prototype was sought and granted through telephone conversations and email communications with GIS manager at NWSC. A preparatory meeting was held with the experts to organize test sessions at NWSC. This session was very practical because the team was highly knowledgeable and could easily navigate around the studio.

Subsequent to applying all the suites, the experts arrived at the decision that DES WAM studio is a positive development of an innovative approach that can be used in the real world for decision-making to support stakeholders in Water Asset Management. Plate 5-3 shows a plate taken during field-testing with the experts at NWSC in Kampala.

Plate 5-3: DES-WAM testing experts at NWSC

In all water utilities, at the end of each session feedback from participants was solicited about the DES-WAM. An in-depth discussion of the evaluation is presented in Chapter 6.

CHAPTER 6
EVALUATION OF THE DES-WAM

This chapter presents the evaluation of the DES-WAM that was conducted to ascertain its usability and usefulness. Section 6.1 presents evaluation objectives. Section 6.2 focuses on evaluation parameters. The evaluation study sites are discussed in section 6.3 while section 6.4 presents the profile of study participants and explores their opinions regarding the DES-WAM. The evaluation tools are presented in section 6.5 and data management and analysis is presented in section 6.6. Section 6.7 focuses on the evaluation results and section 6.8 presents the discussion of findings.

6.1 Evaluation Objectives

The DES-WAM evaluation was done to find out if the studio would enhance decision-making in water asset management. The evaluation was guided by the following objectives:

1. To assess the usability of the DES-WAM studio; and
2. To ascertain the usefulness of the DES-WAM in enhancing decisions in water asset management.

6.2 Evaluation Parameters

Artefacts should be evaluated comprehensively before they are released to the environment (Hevner, 2007). In addition, actual implementation with actual acceptance and usage may be conditioned by other factors not directly related to the artefact or the theory; for example, managerial support, resource availability or change management (Gonzalez & Sol, 2011).Venable (2010) offers guidance concerning the evaluation activity in design science and appropriate criteria concerning various other goals to be applied in evaluation. The DES-WAM was evaluated to ascertain its usefulness and usability. Usability focused on the perceived ease of use of the studio by the decision-makers to enhance decisions on water asset management (Endsley, 1995). Usability focused on ascertaining whether the studio is accessible, provides visualization on incidents reported, supports navigation, supports insights at the level of consensus,

supports knowledge sharing, provides effective guidelines on decision-making, supports expert facilitation or is easy to use.

Usefulness, on the other hand, assessed the effectiveness and relevance of the studio in enhancing water asset management decisions (Mirembe, 2015). The measure of usefulness focused on whether the studio provides structure to a collaborative process, enables divergent brainstorming, facilitates a converging process, allows for the selection of asset maintenance alternatives or improves productivity of the participants.

6.3 Study Sites

The evaluation was carried out in three water management utilities where the studio was implemented, namely National Water and Sewerage Corporation in Kampala, Uganda; Nairobi City Water and Sewerage Corporation (NCWSC); and Kisumu Water and Sewerage Company, Kenya. The above organizations were selected to participate in the study because of two reasons: cost implications and the utilities had taken part in the Asset Management Workshop at Rand Water, Johannesburg, South Africa.

6.4 Study Participants

The evaluation was conducted among categories of users and respondents, namely the experts at the operational, tactical, and strategic levels. In total, 34 people participated in the study. Out of these, 21 were from KIWASCO, 10 from NCWSC and 3 from NWSC. These participants were purposively selected because of their involvement in asset management. Therefore, they were believed to be better placed to understand the studio in terms of its usability and usefulness.

6.5 Evaluation Tools

A semi-structured survey questionnaire was employed as the main tool for collecting data from the study participants. The tool was preferred semi-structured to allow collection of both quantitative and qualitative data. The use of mixed methods designs expands the research in a way that a single approach cannot make it more comprehensive (Moss, 2015). The tools were developed, discussed, piloted and pre-tested to ensure data quality. After the pre-test, the tool was refined and administered to the study respondents.

6.6 Data Management and Analysis

Data were analysed using the Statistical Package for Social Scientists (SPSS) version 16. Nominal/categorical scaled data were presented using frequency counts and percentages. According to Sekaran (2003), nominal/categorical variables of yes/no are analysed and presented using frequency counts and percentages. The interval scaled items in the questionnaire were analysed and presented using means and standards deviations as propounded by Sekaran (2003). The mean portrays the average response on a statement and standard deviation portrays the extent to which scores deviate from the mean (Amin, 2005).

Qualitative data were analysed using content analysis. Responses were grouped into recurrent themes. The recurrent themes, which emerged in relation to each guiding question, were presented in the results, with selected direct quotations from participants offered as illustrations (Mugenda & Mugenda, 1999). The next section presents the evaluation results.

6.7 Evaluation Results

The studio was evaluated for usability and usefulness. This section presents both the quantitative and qualitative findings on the usability and usefulness of the DES-WAM. First, results for usability are presented.

Usability

Table 6-1: Quantitative results showing usability opinions for the DES-WAM

Statement	NWSC Kampala (N=3)		NCWSC Nairobi (N = 10)		KIWASCO Kisumu (N=21)	
	Yes	No	Yes	No	Yes	No
Usability						
Are you able to gain access to the studio using the credentials provided?	3(100%)	0(0%)	10(100%)	0(0%)	19(90.5%)	2(9.5%)
Does the dashboard provide insight on incidents displayed using markers?	3(100%)	0(0%)	10(100%)	0(0%)	19(90.5%)	2(9.5%)
Does the complaints suite provide visualization on incidents reported?	3(100%)	0(0%)	9(90%)	1(10%)	21(100%)	0(0%)

Statement	NWSC Kampala (N=3)		NCWSC Nairobi (N = 10)		KIWASCO Kisumu (N=21)	
Does the studio support navigation?	3(100%)	0(0)	10(100%)	0(0%)	21(100%)	0(0%)
Does the studio provide insight at the level of consensus?	3(100%)	0(0)	10(100%)	0(0%)	21(100%)	0(0%)
Does the studio support knowledge sharing?	3(100%)	0(0)	10(100%)	0(0%)	21(100%)	0(0%)
Does the studio provide guidelines to effective decision-making?	3(100%)	0(0%)	10(100%)	0(0%)	19(90.5%)	2(9.5%)
Does the studio support expert facilitation?	3(100%)	0(0%)	9(90%)	1(10%)	21(100%)	0(0%)
Is it difficult to use the studio?	0(0%)	3(100%)	2(20%)	8(80%)	2(14.3%)	18(85.7%)

The results in Table 6-1 show that the DES-WAM is usability. The study respondents in all the three water utilities noted that the studio was accessible; it provided insights on incidents displayed using markers; and that the complaints suite provided visualization of incidents reported. The study respondents further noted that the studio supported navigation; it provided insight into the level of consensus; and it supported knowledge sharing. They also noted that the studio provided guidelines for effective decision-making; it supported expert facilitation; and it was easy to use.

The respondents were further asked to rate the usability of the studio in terms of how easy it is to learn, use the collaboration tool and understand the user interface. Data were collected on a five-point scale of: 1 = very hard, 2 = hard, 3 = neither hard nor easy, 4 = easy, and 5 = very easy. Table 6-2 presents the users' appreciation of the studio's usability in the three water utilities.

Table 6-2: Quantitative results showing usability ratings of DES-WAM

Statement	NWSC Kampala (N =3, α =0.716)			NCWSC Nairobi (N = 10, α =0.781)			KIWASCO Kisumu (N=21α =0.623)		
	μ	σ	M	μ	σ	M	μ	σ	M
Usa bility									
The collaboration tool is to learn	4.00	0.00	4.00	3.80	0.00	4.00	4.50	0.00	4.00
The collaboration tool is to use	4.00	0.00	4.00	4.00	0.00	4.00	4.00	0.00	4.00
The the user interface is to understand	4.00	0.00	4.00	3.90	0.00	4.00	4.00	0.00	4.00
The studio offers repeatable processes that provide structure and can be run by stakeholders in a collaborative session	4.00	0.00	4.00	3.80	0.00	4.00	4.00	0.00	4.00
The studio enhances collective participation of all stakeholders without fear of victimization on divergent brainstorming	4.00	0.00	4.00	4.50	0.00	4.00	3.95	0.00	4.00
The studio facilitates a converging process where information is used	4.00	0.00	4.00	3.90	0.00	4.00	4.00	0.00	4.00

Statement	NWSC Kampala (N =3, α =0.716)			NCWSC Nairobi (N = 10, α =0.781)			KIWASCO Kisumu (N=21α =0.623)		
	μ	σ	M	μ	σ	M	μ	σ	M
DES-WAM offers facilitation scripts to create a predictable pattern of collaboration on decision-making.	4.50	0.00	4.00	4.00	0.00	4.00	4.40	0.00	4.00
The DES-WAM provides guidelines and scripts with facilitation to achieve the meeting objectives.	4.00	0.00	4.00	3.90	0.00	4.00	3.80	0.00	4.00
The DES-WAM provides a knowledge base and training in asset management creating awareness on the subject given.	3.80	0.00	4.00	3.50	0.00	4.00	3.50	0.00	4.00
Overall Mean	**4.03**	0.00	**4.00**	**3.92**	**0.00**		**4.01**	**0.00**	**4.00**

Notes:

- μ = mean, σ = standard deviation
- M = mode.
- The Cronbach's alpha for NWSC,KIWASCO and NCWSC (α) > 0.4 indicating a sufficient reliability (Sekaran, 2003)

According to the results in Table 6-2, the study respondents indicated that it was easy to learn and use the collaboration tool. They also noted that it was easy to understand the user interface of the DES-WAM. This means that the studio is usable.

According to the study respondents, the DES-WAM offers repeatable processes that provide structure and can be run by stakeholders in a collaborative session thereby enhancing productivity of sector managers by supporting refinement at the level of decisions and time horizon of the decision in maintenance management. This leads to a reduction in response time to incidents and water losses. Stakeholders can collaborate using the studio to resolve reported incidents for asset maintenance, investment planning and risk management.

The study respondents noted that the DES-WAM enhances collective participation of all stakeholders without fear of victimization on divergent brainstorming which enhances sector manager's ability to think outside the box on issues affecting water infrastructure asset maintenance and how to resolve issues focusing on consensus, agreement, and commitment to decisions.

It was established that the DES-WAM facilitates a converging process. Information is shared and a communication base for collaboration between sector managers focusing on enhancement of decisions processes that influence quality of decisions on maintenance and replacement decisions such as scheduling, planning and prioritization in maintenance management.

The results also demonstrate that the DES-WAM offers facilitation scripts to create a predictable pattern of collaboration on decision-making. The sequence of activities undertaken enable sector managers to effectively select asset maintenance alternatives with an input of risk management which feeds into asset maintenance and investment planning decisions.

It emerged that the DES-WAM improves productivity of sector managers because it provides guidelines as well as scripts with facilitation to achieve the meeting objectives.

The study participants noted that the DES-WAM facilitates improvements in decision analysis for asset maintenance, investment planning and risk management by providing guidelines and scripts to provide facilitation scripts to create a predictable pattern of collaboration on decision-making. The same patterns can be replicated in other collaboration sessions to guide sector managers in their decision-making on issues of water asset management. The study respondents also noted that the DES-WAM provides a knowledge base and training in asset management.

Asset maintenance alternatives generated by the studio

The author was interested in finding out the number of asset maintenance alternatives that were generated by the studio in each of the three water utilities. The results are presented in table 6-3.

The results in Table 6-3 indicate that the studio generated between 5 and 10 asset maintenance alternatives as reported by 23(67.6%) of the study respondents. This means that the studio is useful in generating appropriate water asset management decisions.

Table 6-3: Generated Asset Maintenance Alternatives

			Organization Name			
			KIWASCO Kisumu	NCWSC Nairobi	NWSC Kampala	Total
How many asset maintenance alternatives were generated?	Below 5	Count	8	3	0	11
		percentage within Organization Name	38.1%	30.0%	.0%	32.4%
	5-10	Count	13	7	3	23
		percentage within Organization Name	61.9%	70.0%	100.0%	67.6%
Total		Count	21	10	3	34
		percentage within Organization	100.0%	100.0%	100.0%	100.0%

The study respondents were asked to mention the challenges in using the studio and how it could be improved. Table 6-3 presents the qualitative findings on the challenges and possible improvements that can be made to the studio.

Table 6-4: Feedback on Collaboration Meetings

Challenges/improvements	Illustrative written quotations	NWSC (N=3)	NCWSC (N=10)	KIWASCO (N=21)
List any challenges you may have faced in learning the collaboration meeting				
Access to the Internet	"Accessibility of the site – premise dependent or network dependent"	1		
	"The field personnel who attend to most complaints do not have full access to the Internet/network, so they can't use system fully."	1	4	5
	"Accessing the studio with no Internet is difficult."	1		
	"Network availability."	1		
Being computer illiterate	"Requires one to be technology savvy, which may hamper the uptake because many utility staff are not that computer literate."	1	2	2
	"Navigation requires keenness all the time."		1	1
	"Help page was inaccessible."		2	2
	"The complaint forum would be challenging to select all the complaints."		1	1
Computer hardware	"Lack of enough computers to do it at a personal level."		2	2
Suggest ways of improving it (learning)				
Offline component	"Providing for offline component."	1		
Training	"Organize for more training and awareness sessions."	1	3	1
	"Training and user manual."	1		1

Challenges/improvements	Illustrative written quotations	NWSC (N=3)	NCWSC (N=10)	KIWASCO (N=21)
	"Awareness must be done to staff."			2
	"Continuous use of the tool in order to improve in decision processes."			3
Computer hardware	"Provide more computers for staff."		3	1
Internet access	"Increase the Internet efficiency."		1	
	"Improve the Internet connectivity."		1	
User identification	"Provide option for identifying users while online."		1	
	"Accountability of decisions arrived at after deliberations."		3	
More time	"Allocate more time for such sessions"		1	
	"Limited time (give tests a month)."		1	
List any challenges you may have faced in the use of the collaboration tool				
Users inviting participants	"How about if one of the discussants wants to invite a friend?"	1		
Internet access	"Weak Internet connection."			1
	"The Internet speed, some models not functional and the server not responding. No network"		3	5
Navigation	"Navigation requires a lot of keenness."		1	1
	"Selecting the icons sequentially is a challenge."		2	1
	"Anonymity."		1	1
	"Limited time (give tests a month)."		1	1
Suggest ways of improving it (use)				
Users able to invite participants	"Provide an option to allow the discussant to suggest who to invite to the administrator"	1		
SMS alerts	"SMS alerts used in the prototype are suitable since most of the field staff are not as IT adequate"	1		
Improve Internet	"Improve connectivity to Internet."		2	5
Time	"More time is required to assist participants understand the process."		1	2
	"More time needs to be allocated due to the Internet disruptions."		1	2
	"More testing time for participants to sharpen their skills."		1	2

The respondents were asked to list any challenges that they faced in learning the collaboration meeting. Emerging themes were derived from the responses in Table 6-4, namely limited access to the Internet when using the system, lack of adequate knowledge to use computers and lack of adequate computer hardware. This may be true of emerging economies which still grapple with Internet access for all and low levels of computer literacy. When asked how the collaboration meeting could be improved, the study participants noted that there was need to: introduce an offline component, offer user

training, improve access to computer hardware, improve Internet access and connectivity, provide options for identifying users while online and allocate more time for the sessions. With regard to the challenges faced by the users in using the collaboration tool, the following were highlighted: users could not invite other participants, there was poor Internet access and connectivity, selecting the icons sequentially for a few was a challenge and the time allocated for the session was limited. On improving the use of the collaboration tools, the users noted that there was need to provide an option to allow the discussant to suggest who to invite to the administrator. They also suggested a tool to introduce SMS because "SMS alerts used in the prototype are suitable since most of the field staff are not as IT adequate". Others suggestions for improvement included improving Internet access, increasing time, and training users.

Usefulness

The other parameter which was evaluated was usefulness of the studio in enhancing water asset decisions in the water utilities. Table 6-5 presents the users' appreciation of the usefulness of the studio in enhancing water asset management decisions. The results in Table 6-5 show that the study respondents perceived the studio to be useful in enhancing decisions for water asset management.

Table 6-5: Usefulness of the studio

Statement	NWSC Kampala (N=3)		NCWSC Nairobi (N = 10)		KIWASCO Kisumu (N=21)	
	Yes	No	Yes	No	Yes	No
Does the studio enhance decisions that lead to reduction in non-revenue water?	3(100%)	0(0)	10(100%)	0(0%)	21(100%)	0(0%)
Does the studio enhance decisions that lead to water leakage reduction?	3(100%)	0(0)	10(100%)	0(0%)	20(95.2%)	1(4.8%)
Does the studio enhance decisions that lead to increased response time?	3(100%)	0(0)	10(100%)	0(0%)	21(100%)	0(0%)
Does the studio enhance decisions that lead to increased knowledge about the water pipe network systems?	3(100%)	0(0)	10(100%)	0(0%)	21(100%)	0(0%)
Does the studio enhance decisions which lead to increased fire fighting capability by the water utility?	2(66.7%)	1(33.3%)	10(100%)	0(0%)	17(81.0%)	4(19.0%)
Does the studio enhance decisions which lead to reduced property damage?	3(100%)	0(0)	10(100%)	0(0%)	20(95.2%)	1(4.8%)
Does the studio enhance decisions which lead to reduced risk of water contamination?	3(100%)	0(0)	10(100%)	0(0%)	21(100%)	0(0%)

Statement	NWSC Kampala (N=3)		NCWSC Nairobi (N = 10)		KIWASCO Kisumu (N=21)	
	Yes	No	Yes	No	Yes	No
Does the studio enhance decisions which lead to more stabilized water pressure throughout the system?	3(100%)	0(0)	10(100%)	0(0%)	21(100%)	0(0%)

The study respondents noted that the studio enhances decisions that lead to: reduction in non-revenue water, water leakage reduction, increased response time to customer needs and increased knowledge about the water pipe network systems. The respondents further noted that the studio enhanced decisions which lead to: increased fire fighting capability by the water utilities, reduced property damage, reduced risk of water contamination, and more stabilized water pressure throughout the system.

Table 6-6: Quantitative results rating usefulness of the studio

Statement	NWSC Kampala (N =3, α =0.000)			NCWSC Nairobi (N = 10, α =0.781)			KIWASCO Kisumu (N=21)		
	μ	σ	M	μ	σ	M	μ	σ	M
Usefulness									
Usefulness of the collaboration meeting for the generation of asset maintenance alternatives	4.00	0.00	4.00	4.00	0.00	4.00	4.00	0.00	4.00
Suitability of the collaboration meeting for the generation of asset maintenance alternatives	4.00	0.00	4.00	3.90	0.00	4.00	4.00	0.00	4.00
How would you rate the suggested asset maintenance alternatives?	4.00	0.00	4.00	4.00	0.00	4.00	4.00	0.00	4.00
Overall Mean	**4.00**	**0.00**		**3.96**	**0.00**		**4.00**	**0.00**	

The study respondents rated the usefulness of the studio to be satisfactory at overall mean 4.00. They mentioned that the collaboration meeting for the generation of asset maintenance alternatives was good at mean μ 4.00. They also rated the suitability of the collaboration meeting for the generation of asset maintenance alternatives is good. They positively rated the suggested asset maintenance alternatives as good at the overall mean μ 4.00. For all three cases, Cronbach's alpha (α) > 0.4 indicates a sufficient reliability (Sekaran, 2003).

6.8 Interpretation and Discussion of Results

Usability

The results of this study show that the DES-WAM is usable as noted by all the respondents in all the 3 water utilities. Usability may increase the adoption of the studio since adoption of any information technology system depends largely on how usable it is (Shawn et al, 2006). During the evaluation stage of this study, it was discovered that the staff in the water utilities did not have adequate capacity to manage water assets with the use of IT systems as attested to by a respondent at NCWSC-Kenya who cited the "Human resource capacity gap" as one of the challenges to effective asset management in the water utility (see appendix D). Thus, a studio like DES-WAM which is easy to use can enhance adoption and use of IT systems in the management of water assets among staff who are not highly tech savvy. To underscore this fact, the C.E.O of Kisumu Water & Sewerage Company requested to immediately use the studio for their work after we implemented the DES-WAM at KIWASCO.

Usefulness

The evaluation results indicate that the DES-WAM is useful in enhancing decisions in water asset management. Its usefulness was rated to be good. Therefore, the DES-WAM is useful and relevant in addressing the decisions that matter in water asset management as highlighted. This implies that the studio can be used by the water utilities to come up with decisions that can enhance asset management because DES-WAM is a service system comprising of people, technology and processes. It provides a collaborative decision-making environment for enhancing sector managers' maintenance management decisions, by facilitating: shared information, visualization, structure and repeatable processes, predictable patterns, collective participation, facilitation, a knowledge base and training for sector managers and stakeholders in water asset management via services packed in studios, guidelines and suites. The new orientation has been on developing a range of strategic responses to safeguard the large public and private investments in water assets. These practices can be based on asset management systems like DES WAM through which businesses focus on services rather than engineering and reduce their exposure to risk while reducing operating costs and capital spending (Lloyd, 2012) and

hence DES WAM as observed by Lloyd (2012) and confirmed by the end users in all the water utilities that participated in the study.

This chapter generally shows that the DES-WAM is usable and useful in enhancing water asset management decisions. The next chapter presents the epilogue to the study.

CHAPTER 7

EPILOGUE

The research presented in this thesis involved developing a decision enhancement studio that facilitates complex asset management decisions by providing services to enhance decision-making in small to medium water and sanitation utilities in transitional countries. It was specially carried out with sector managers in the following water companies: Rand Water, Johannesburg, South Africa; Waterbedrijf Groningen, The Netherlands; National Water and Sewerage Corporation, Uganda; Nairobi City Water and Sewerage Company, Kenya; and Kisumu Water and Sanitation Company, Kenya. Additional insights were gained from experts and Water Asset Management workshop held with several water companies of Sub-Saharan Africa in Johannesburg, South Africa. As an element of the research contribution, the research among others sought to develop solutions to the Sector managers' decision-making challenges. Subsequently, the approach that structured the study activities consisted of initiation, abstraction, theory formulation, implementation and evaluation. In the epilogue, the author provides a shortened overview of the overall thesis covering a brief introduction, problem domain, research objective, philosophy and strategies. Furthermore, reflections regarding the adopted research solution as well as suggestions for future research are presented.

7.1 Introduction

According to Van Aken (2005), the main goal of design science research is to develop knowledge that the professionals of the discipline in question can use to design solutions for their field challenges. Hevner et al., (2004) postulated that the main purpose of design science research is to achieve knowledge and understanding of a problem domain by building and applying a designed artefact. Gregor & Hevner (2013) specify that, development of a particular novel artefact with high utility can be seen as a contribution to knowledge. The artefact permits the researcher to get a better understanding of the problem and re-evaluation of the problem improves the quality of the design process. This build-and-evaluate loop is iterated a number of times before the final design artefact is produced (Markus et al., 2002). Design science research encompasses two types of knowledge, namely descriptive and prescriptive (Gregor and Hevner 2013). As argued in

the sections that follow, this study has contributed to both dimensions of knowledge, as well as making recommendations based on insights gained during its verification and evaluation exercise. In particular, descriptive knowledge is created through problem landscaping, analysis of the sector managers' decision-making challenges, exploratory studies together with an approach to design the studio.

Prescriptive knowledge consists of constructs, models, methods and instantiations (Gregor and Hevner, 2013), and it has been created through designing, instantiating and implementing, as well as evaluating the studio among sector managers. This has involved obtaining sector managers' decision-making requirements; generating two abstract models of the desired studio, describing design methods employed including guidelines and scripts for using the studio. A design theory is created by means of an abstract representation of the studio, which starts from conception and initiation (Chapter 1), further understanding, and exploration (Chapters 2 and 3), design as an artefact (Chapter 4), instantiation and realization (Chapters 5 and 6). Therefore, this research has generated design knowledge, which is summarized in this chapter covering an overview of the problem domain, reflection on the research objective, theory formulation, instantiation, evaluation and future work. In addition, it is argued that the studio notion advanced by Keen and Sol (2008) is useful in the problem domain.

7.2 Overview of the Problem Domain

As an initiation to the problem domain, it was recognized that the maintenance, rehabilitation, and replacement of the assets that make up the water infrastructure are constant. The initial literature survey in this study revealed that one of the major challenges faced by water utilities in transitional countries is ineffective decision-making in water asset management. This has resulted into many inherent issues like leakages in the pipe networks with the poor condition of the existing infrastructure, and high levels of non-revenue water (Mugisha & Berg, 2008; NWSC, 2009). Making decisions that matter, decisions that are urgent, consequential and permanent becomes imperative but also more difficult. The exploration and literature review phase of this research resulted in the three water asset management decision-making challenges and several

observations, confirming that decision-making in the water domain can be characterized as a complex and wicked problem (Head & Alford 2014).

Sector managers' decisions that matter included decisions on maintenance, rehabilitation, and replacement (asset management); decisions on investment planning to inform prioritization especially depending on the scope that is, short-term medium-term for replacement/refurbishment in the areas of tactical/operational levels. Others are decisions on risk management which inform the decisions on asset maintenance and investment planning. Similarly, the situation is made complex due to such factors as existing policies, governance, culture, regulatory bodies, operating and ownership structures, and customer service requirements. The other factors are socio economic, political, environmental, and technology and business objectives (Pudney, 2010). Water and sanitation companies are more focused on engineering solutions while placing little emphasis on services. Lloyds (2012) further observes that businesses should focus more on services rather than engineering in order to reduce exposure to risk, operating costs and capital spending. As Keen & Sol (2008) argue, decision enhancement provides services to guide a journey where executives, their advisors, change management, specialists, experts in multi-disciplinary fields and technology developers can come together to make a substantive new impact on effective decision-making in any organization. It is in this perspective that this study was initiated.

The initial literature survey in this study revealed that one of the major challenges faced by water utilities in transitional countries is ineffective decision-making in water asset management. This has resulted into many inherent issues like leakages in the pipe networks with the poor condition of the existing infrastructure, and high levels of non-revenue water (Mugisha & Berg, 2008; NWSC, 2009). According to Kingdom et al., (2006), most water utilities in transitional countries have NRW that exceeds 50%. There is also growing evidence which suggests that the integrity of drinking water and wastewater infrastructure is at risk. This is because there is no collaborative effort to improve the management of key assets such as pipelines, treatment plants, and other facilities coupled with lack of significant investment in maintaining, rehabilitating, and replacing these assets (Bhagwan, 2009). When asked to mention the key challenges to

achieving effective asset management, one of the respondents from KIWASCO mentioned "the lack of detailed information on existing assets managed by the company" as one of the challenges of asset management. Similarly, "lack of an updated asset register" was reported by a respondent in KIWASCO as a key challenge to asset management. From the above observations, it is clear that effective water asset management in the water utilities is constrained by lack of adequate information systems that can enhance water asset management decisions. The above challenge provided us with the motivation for designing a decision enhancement studio which would support sector managers at the strategic, tactical and operational levels to enhance decisions in asset management amongst water utilities. The studio would thus forestall the challenge of systems in the water utilities that do not talk to each other and eliminate the problems of limited monitoring by information sharing. Consequently, the motivation for the study was to develop, prototype and evaluate a decision enhancement studio which would facilitate complex asset management decisions through providing services to enhance decision making in water infrastructure asset management, particularly maintenance management. We envisaged that the decision enhancement studio for water asset management would provide services that would enable stakeholders come together to make effective decisions on maintenance management. This is because collaboration among stakeholders on decisions that matter is important in instituting asset management practices amongst utilities (Keen & Sol, 2008). The objective of design science research is to develop technology-based solutions to important and relevant business problems (Hevner, 2007).

7.3 Reflection on Research Objective

The main objective of this study was "to develop a decision enhancement studio that facilitates complex asset management decisions through providing services to enhance decision-making". The research objective was addressed using insights from the design science paradigm of Hevner et al., (2004) and Hevner (2007). The design science approaches enabled rigorous analysis and development of a decision enhancement studio founded on the decision enhancement lens of Keen & Sol (2008). This design science research philosophy is effectuated with the inductive-hypothetic research strategy of Sol

(1982) to facilitate problem initiation, abstraction, theory formulation, solution implementation and evaluation.

Designing in the problem domain was concerned with the design and management of "a decision enhancement studio for water asset management" as the resulting artefact, which provides collaborative decision-making opportunities to sector managers and other stakeholders. Insights from collaborative engineering were helpful during the design and development of the identified services (Briggs et al., 2003). From the design science perspective, an inductive-hypothetical research strategy advanced by Sol (1982) was used to facilitate problem initiation, abstraction, theory formulation, solution implementation and evaluation.

Explorative procedures were used to obtain sector managers' decision-making requirements (Trochim, 2006). The research particularly employed literature reviews, unstructured interviews and observations for gaining an increased understanding of the water infrastructure management domain requirements. Whereas from the results sector managers' have many requirements, the study focused on asset maintenance, investment planning and risk management decisions. Key factors that influence these decisions were identified, namely existing policies, governance, culture, regulatory bodies, operating and ownership structures, customer service requirements, socio economic factors, political factors, economic factors, environmental factors, technology and business objectives (Pudney, 2010)., etc. These factors, among others, helped in conceptualizing the proposed sector managers' decision enhancement services. The exploratory investigations also helped in gaining knowledge on the resources required (and potentially available) for designing, prototyping and testing a decision enhancement studio for water asset management. It was also necessary to engage sector managers and other stakeholders at all stages of the studio design and implementation. Insights were gained from Yin (2003). Through exploration, it was further possible to engage sector managers and other stakeholders.

Distinctively, exploration enabled to address three key issues: participation, facilitation and location.

i) **Participation**: the sector managers and stakeholders using the studio are invited to take part in a collaborative effort to address decisions that matter. DES-WAM aims at encouraging the involvement of stakeholders in the decision processes that is most likely to lead to consensus, agreement and decision commitment. The DES-WAM design is built with interactive tools and suites to enhance decision processes. For instance, in the stakeholders' brain storming stages of a decision process, the group handles ranking alternatives, voting on next steps and making and responding to comments. The system decides for them whether to make the communications anonymous. Sector managers requested for anonymity for fear of victimization. DES-WAM configurations can have influential effects on the patterns of interactions among stakeholders leading to desired organisation changes.

ii) **Facilitation**: trust and legitimacy can be built into what is proposed by the decision enhancement studio, and a skilled facilitator intervenes and adapts the system to the group to make the most of their deliberations. Sector managers have the confidence that there is support for a self-sustaining community and not like consultants who leave after introducing a solution with nobody remaining to run technology on behalf of teams.

iii) **Location**: outcomes and outputs are more realized since sector managers and stakeholders can be reached virtually for their inputs on decisions in water infrastructure asset management. Challenges of low productivity due to absenteeism in meetings helped to inform the design that leads to a better artefact.

In conclusion, based on the research objective, a number of key considerations have been recommended.

i). Designing and implementing a decision enhancement studio for sector managers' and stakeholders should be positioned within an organizational context with the researcher as an active participant in solving practical problems in the course of

studying them. For this study, the author has paid attention to sector managers and stakeholders' decision challenges.

ii). Communication of the research and outcome of this study to both the technology-oriented and management-oriented audiences is needed to encourage wider engagement of sector managers, experts and the research community, which may lead to additional insights and new research plans.

iii). In designing similar services for sector managers, it is a requirement to ensure that the design is shaped by the users that is user-centric, personalized, process enabled, and participatory. Personalization makes it possible to enable sector managers' and other stakeholders to work together to carry out asset maintenance, investment planning as well as manage risk leading to services which are user-cantered,

iv). To improve the utility of the studio, it is vital to define correctly maintenance management decision-making activities of sector managers at the operational and tactical levels in small and medium water and sanitation companies. These activities facilitate and inform the design, instantiation and evaluation of the studio amongst a specific group of sector managers and other stakeholders.

7.4 Theory formulation

According to Venable (2006), literature on design science has been mixed on the inclusion, form, and role of theory and theorizing in design science. For design science research to gain wide credibility as a research paradigm in information systems (IS), it must contribute to theory (Alturki & Gable, 2014). Reviewed literature attests to the need for theory and theorizing as important ingredients in design science research (Goldkuhl, 2013; March & Smith, 1995; Markus et al., 2002; Nunamaker et al., 1991). Therefore, owing to the importance of theory in research, considerable efforts have been made to understand better the process of theorizing. Lee et al., (2011) suggest two dominant theorizing approaches, deductive and inductive reasoning. In contrast, an essential part of theorizing for design may involve abductive reasoning. Lee et al., (2011) further denotes that design theory seeks to guide learning and problem solving through the conceptualization of a design artefact. In this study, theory formulation results in the

creation and implementation of an artefact (Aregu, 2014; Hevner et al., 2004; Knol, 2013), "a decision enhancement studio for water asset management".

Insights from Nunamaker et al., (1991) informed this research's theory building, systems development, observations and field experimentations. Observations and experimentations were critical elements of the evaluation presented in Chapter six. This part provides a shortened discussion on theory building and covers the development of new ideas and concepts on sector managers' decision-making. It is also concerned with the construction of the conceptual overview, new methods and models (Sol, 1982; Gonzalez & Sol, 2012). The theorizing strategy is further enlightened by insights from abductive reasoning as shown in Lee et al., (2011), Vaishnavi & Kuechler (2004) and Gonzalez & Sol (2012).

The focus of theory formulation was on defining key service values that the proposed decision enhancement service seeks to offer to primary users- mainly "sector managers and stakeholders". This necessitated active engagement with sector managers and other stakeholders, which started at an early stage in order to understand the empirical water asset management decision-making needs of sector managers. Venable and Baskerville, (2012) affirm, "that a purposeful artefact refers to any kind of artefact designed to achieve some human purpose", the decision enhancement studio for water asset management in this case. The domain need for active engagement significantly adds to the design science knowledge base of Hevner et al., (2004). Likewise, Van de Ven (2007) and Sol (2014) refer to engaged scholarship, which in effect represents the process of active engagement. Embracing sector managers and encapsulating their critical institutional knowledge into the design seeks to ensure that the studio is more reflective of the sector managers' systems and perhaps more appealing to them. In addition to literature review, expert feedback, the engagement process enabled realization of new ideas, concepts, requirements and constraints relevant for building the proposed decision enhancement studio for water asset management. Consequently, a theory is proposed based on the sector managers' decision-making activities in maintenance management, and involving three aspects of people, process and technology (Keen & Sol, 2008).

In general, results of this study indicate that the studio concept is suitable for addressing the sector managers' asset maintenance, investment plans and risk management decision-making requirements. This is because many of the water asset management decision-making challenges faced by sector managers' arise from causes that are governance in nature. Therefore, the aim was to design a service system, which would enhance sector managers' maintenance management choices. Design service systems in this kind of domain are hard to manage and understand owing to their non-linear multi-scale dynamics, the potential for rapid change in the service drivers and the reflexivity of human action (Aregu, 2014; Mulira, 2007; Van de Kar, 2004). Nevertheless, by analysing information systems development methodologies using the "ways of" framework (Seligmann et al., 1989; Sol, 1988), further insights to handle the problem domain were gained. Additional insights were obtained from exploration and feedback from experts. Similarly, since collaborative decision-making is essential for effective maintenance management by sector managers, insights from collaborative engineering (De Vreede et al., 2003; De Vreede & Briggs, 2005) were essential. Given the domain characteristics, more useful insights were gained from the 4Es shared value, namely engaged, empathetic, embedded and evolving propounded by Sol (2014). The challenge of ageing infrastructure as it relates to distribution assets, limited funding and regulatory compliance issues dare sector managers to do more with less while keeping focus on the future. Hence, other necessary knowledge was required from the asset management specifications which are described in Section 2.3.

In Chapter 4, it has been concluded that DES-WAM is a service system comprising of people, technology and processes. It provides a collaborative decision-making environment for enhancing sector managers' maintenance management decisions, by facilitating shared information, visualization, structure and repeatable processes, predictable patterns, collective participation, facilitation and a knowledge base and training for sector managers and stakeholders in water asset management via services packed in studios, guidelines and suites.

Commencing from literature and exploratory results, a better understanding of an approach to design DES-WAM was formulated around several concepts. Some of these concepts mainly comprise key activities performed by sector managers during maintenance management decisions, specific tasks that are to be undertaken to attain a particular decision outcome and processes that need to be carried out including considerations of enabling technology. These have been structured and presented following the decision enhancement framework of Keen and Sol (2008) involving people, process and technology aspects. For the problem domain, key activities had to be identified through abstraction including their interaction (Chapter 4). Similar to Aregu's (2014) discussions, DES-WAM enhances sector managers' decisions by facilitating collaborative decision-making; largely enabling information sharing, information visualization, brainstorming, ranking, rating, voting, selection of alternatives and feedback and learning. Results equally suggest that DES-WAM enhances sector managers' ability in identifying maintenance management incidents, conceptualization, empirical definition of the problem, solution formulation, and leading to implementation. This is in line with the earlier arguments of Sol (1982) regarding choice making by decision-makers who are faced with ill-defined problems.

7.5 Instantiation

It has been instantiated through prototyping and implementation of the DES-WAM as it is presented in Chapter 5. The rationale of instantiation was to determine the performance of the proposed decision enhancement studio for water asset management, a service packed in technology suites, guidelines and scripts and underpinned by Keen and Sol's (2008) concept of decision enhancement. Therefore, from a philosophical perspective, the study at this stage sought to actualize an artefact in the form of an instantiation (Hevner et al., 2004; Gregor & Hevner, 2013). In general, DES-WAM instantiation was intended to show its feasibility in terms of the design process and of the resulting decision enhancement studio.

Throughout instantiation, it embodied DES-WAM as a versatile service system where introducing new technologies and methods could add more intricacy to sector managers'

decision-making process. This could alter the presented sector managers' decision-making processes and requirements. Visualization of reported incidents was identified as the critical component of DES-WAM since it is required to aid collaborative decision-making among sector managers and stakeholders. Hence, in understanding information requirements of sector managers' decision-making, it was necessary to break the critical component into sub-categories based on a generic ontology. At this stage, the search for an effective problem representation was crucial for finding an effective solution for enhancing stakeholders' maintenance management decisions. This agrees with the knowledge base where Simon (1996) discusses the creation of innovative artefacts to solve real problems and that Design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation (Hevner et al., 2004).

Furthermore, DES-WAM functionality had to be instantiated based on identified activities and tasks, and with the help of available technologies. There was need to improve the understanding of DES-WAM instantiation, and particularly to look at mechanisms leading to its successful performance. Hence, at the instantiation phase, efforts on the suggestion of available resources were directed to achieve sector managers'/stakeholder's decision-making goal. At this stage of design and development, it was important to ensure instant representation of stakeholders', their decisions that matter, requirements, opportunities and constraints. In this way, the studio design and development may permit stakeholders' to change and focus on their core activities, and hence benefit from the studio services. However, no single or special methodology was used to develop the studio. A combination and adaptation of methods and empirical techniques with the overarching goal were adopted. As a result, the study established that the studio was: 1) extremely easy to use and understand, 2) used by practitioners in maintenance management, 3) organized knowledge in science, 4) surviving throughout time, and 5) providing real time information to sector managers/stakeholders.

Empirically, DES-WAM instantiation strategy focused on the use of Internet as both an information resource and communication base for collaboration within sector managers. However, it also goes beyond in two important regards: a focus on enhancement of the

processes that influence the quality of decisions that really matter in water asset management and the training mode provides a knowledge base on asset management to support stakeholders gain a common understanding on the issues pertaining to water asset management. Learning studios become vehicles for training (Keen & Sol, 2008). Skills are crucial and most companies have employed training programs to build teams, facilitate change and leadership (Keen & Sol, 2008). The training suite is adapted to get stakeholders acquainted with the DES-WAM prototype and create understanding about what constitutes water asset management and how decision processes can be enhanced.

Specifically, the studio verification mainly focused on service accessibility, insights on incidents displayed using markers, visualization of incidents reported, navigation, and training. It also focused on insight into the level of consensus and knowledge sharing, guidelines for effective decision-making and expert facilitation, repeatable processes providing structure in a collaborative session in level of decisions, and time horizon of the decisions in maintenance management. From verification of the results, the DES-WAM therefore, enhances the maintenance management decision processes by providing the much needed support of collaboration as well as addressing most of the challenges facing stakeholders involved in this process. Sector managers/stakeholders were able to access and use the studio suites and services. The sector managers/stakeholders made recommendations on some modification and improvements to the studio design and implementation.

7.6 Evaluation Exercise

Basing on the design science evaluation the utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods (Gregor & Hevner, 2013; Hevner et al., 2004); this was presented in Chapter 6. This exercise relates to observation and experimentation in design science as described by Nunamaker et al., (1991). Completed by the behavioural science theory, evaluation of DES-WAM required the definition of appropriate methods, gathering and analysis of appropriate data. Empirically, DES-WAM evaluation was performed following the Keen & Sol's (2008) constructs of usefulness and usability. In addition, the evaluation exercise utilized

methods and techniques obtainable within existing knowledge base. Therefore, the author provides an epilogue of the evaluation process and its results under this section.

During the evaluation exercise, the researcher began with planning to ascertain *how to* reflect and re-define research domain point of view, set out boundaries, re-define key stakeholders and their roles, gain insight into resources and present evaluation strategies to respondents. From the insights of user-centred methodologies (Nielsen, 1993; Ryser & Glinz, 1999; Van de Kar, 2004), key decision scenarios were utilized to capture the studio's functionalities and constraints. Evaluation results were analysed using strategies not involving any assumptions as to the form or parameters of frequency distribution (Brown & Saunders, 2008) because the instruments used generated taxonomic data (Brown & Saunders, 2008;Trochim, 2006). Analysed results are presented in Chapter 6.

On usefulness evaluation, results show that the studio helps enhance sector managers' maintenance management decision-making process leading to reduction in non-revenue water, water leakage reduction, increased response time to customer needs and increased knowledge about the water pipe network systems. There is also empirical evidence that the studio can enhance sector managers' and stakeholders other decisions such as meetings that do not concern maintenance management. Though this could need further investigation, results seem to suggest a direct relationship between the studio usefulness and the sector managers' rate of collaboration. In general, the studio's usefulness is reflected on the following decision tasks:

i). Facilitating increased fire fighting capability by decision-makers to cut back on response time thereby reducing water losses;
ii). Enabling reduction of property damage through fast information on leakage, decision-makers are alerted and they can take immediate action;
iii). Promoting collaboration among sector managers on water asset management, particularly maintenance management;
iv). Enabling reduced risk of water contamination by using crowd sourcing to alert decision-makers on incidents; and
v). Promoting more stabilized water pressure throughout the system to provide better quality service.

On evaluation of usability, the main aim was to measure how easy and understandable were the studio interface, language and context to the users. Usability focused on the perceived ease of use of the studio by the decision maker to enhance decisions on water asset management. Usability focused on ascertaining whether the studio is accessible, provides visualization on incidents reported, supports navigation, supports insights at the level of consensus, supports knowledge sharing, provides effective guidelines on decision-making, supports expert facilitation and is easy to use. The usefulness and usability evaluation is equally explored in Chapter 6.

7.7 Conclusions and Research Agenda

Decision enhancement as presented by Keen and Sol (2008) could compel advancement in improving sector managers' decision-making in water infrastructure asset management, particularly maintenance management for small to medium water and sanitation utilities in transitional countries. However, to understand any potential benefits, and overall effects on water asset management environment, there is need to examine the organizational and social issues surrounding stakeholders' decision-making processes. This study focused on the sector managers' asset maintenance, investment planning and risk management (maintenance management) decision-making arenas with the case of small to medium water and sanitation utilities in transitional countries. The results of this study could be used within a general research landscape to facilitate development of additional research ventures. Besides, the decision-making research landscape shows the process of research and how it relates to operational aspects of service delivery to sector managers'/stakeholders. Therefore, in this section, the author focuses the attention on briefly describing the contribution of this research and some of the issues that require further consideration. This research is summarized in table 7-1 derived from Gregor and Hevner (2013).

Table 7-1: Summary of the research

Section	Contents
Introduction	The problem domain presented in chapter 1 defines the relevance and goal of the study. The objective was to develop a decision enhancement studio that facilitates complex asset management decisions through providing

Section	Contents
	services to enhance decision-making.
Literature reviewed	Preceding knowledge regarding sector managers and stakeholders' asset maintenance, investment planning, and risk management decision-making practices are discussed, including different design approaches. The design approaches are particularly reviewed using the "ways of" framework. Furthermore, literature on decision support systems and sector managers'/stakeholders maintenance management decisions is covered. The literature helps our understanding of the instantiation and evaluation exercises.
Method	The research tags on decision enhancement theory (Keen & Sol, 2008). Founded on design science (Hevner, 2007; Hevner et al., 2004), an inductive-hypothetical strategy is employed to better understand the sector managers of water asset management, particularly maintenance management decision-making arenas. This is followed by an exploratory field study involving groups of purposively selected sector managers from the study areas. The exploratory study is discussed in Chapter 3. Based on the "ways of" framework (Seligmann et al., 1989), the three aspects of decision enhancement (Keen & Sol, 2008), an approach to design the studio are presented in Chapter 4.
Artefact description	From a number of insights such as Aregu, (2014); Diana et al., (2009); Hevner et al., (2004), the studio is instantiated and described in Chapter 5. This involves prototyping and implementation among different groups of sector managers'/stakeholders.
Evaluation and discussion	The studio was evaluated using Keen and Sol's (2008) constructs of usefulness and usability. These constructs were specially evaluated using frequency counts and percentages, means and standards deviations as well as content analysis (Sekaran, 2003; Amin, 2005; Mugenda & Mugenda 1999). The evaluation results and discussions are explicated in Chapter 6. Generally, the results indicate the studio is useful among sector managers since it meets their maintenance management decision needs. Hence, from landscaping to exploration, and to an approach to design the studio, the study contributes a theory for design and action (prescriptive knowledge) (Gregor & Hevner, 2013). A contribution to maintenance management decision-making challenges adds to the descriptive knowledge base.
Conclusions	Overall, the work is presented in this thesis, including recommending a research agenda.

Contributions

This study has contributed to the literature on decision enhancement, and particularly sector managers and stakeholders' decision-making processes, in two ways. First, it has managed to develop, implement and evaluate a relevant artefact, the Decision Enhancement Studio for Water Asset Management (DES-WAM) targeted towards the sector managers'/stakeholders' maintenance management decision related tasks. Secondly, it proposed design principles for the problem domain. From the results of exploratory study and literature review, one of the key weaknesses with existing systems

is ineffective decision-making in water infrastructure asset management, particularly maintenance management. Poor maintenance management leads to a significant investment in maintaining, rehabilitating, and replacing these assets (Bhagwan, 2009) not to mention the resulting effects of non-revenue water due to operational inefficiencies (World Bank, 2006; Wyatt, 2010). For DES-WAM, a "Mobile Application" has been incorporated with the Dashboard Visualization Suite to facilitate capturing of information and relaying feedback to stakeholders on complaints reported and how they are resolved via SMS.

Research Agenda

Similar to any other scientific inquiry, this research has created an avenue for further investigations on sector managers'/stakeholders maintenance management decision-making arenas. Several issues that may necessitate further exploration include:

i). The need to implement and evaluate the studio among water utilities in developed countries;
ii). The need to have the DES-WAM evaluated by users for small to medium water and sanitation utilities that were not exposed to the studio in other transitional regions;
iii). Consideration for using bulk water suppliers as case studies for purposes of generalizing findings and conclusions; and
iv). Investigating the adaptation or expansion of the studio.

Therefore the following recommendations are given:

Recommendation 1: The DES-WAM was prototyped, implemented and evaluated among three water utilities in transitional countries which face unique challenges like lack of adequate infrastructure, technical capacity and inadequate funding. There is need to implement and evaluate the studio among water utilities in the developed countries in order to validate its usefulness and usability. This will allow for the generalization of the study findings.

Recommendation 2: There is need to have the DES-WAM evaluated by users for small to medium water and sanitation utilities who were not exposed to the studio in other transitional regions as a way of ascertaining its usability and usefulness. This

will enable comparison of their results with ours in order for us to generalize the studio.

Recommendation 3: Future research should consider using bulk water suppliers as case studies and larger samples of respondents for purposes of generalizing findings and conclusions on the usability and usefulness of the DES-WAM.

Recommendation 4: More studies should investigate the adaptation or expansion of the studio prototype to cater for other non-revenue water causes; larger bulk water and sanitation utilities with more mature IT system landscapes (including systems integration); broader and/or strategic longer term infrastructure asset management decisions including more support for this studio. Or even emergency or disaster related water infrastructure decisions (such as a "war room" scenario) which may require integration with a control system or systems (for example, SCADA type of system).

EPILOGUE

SUMMARY

This study was sparked by reports about the challenges of water asset management in transitional countries (Ardakanian & Martin-Bordes, 2007). The study began by exploring the key water asset management challenges faced by water utilities in providing clean water and managing water assets. The initial studies revealed that water utilities were faced with a number of challenges, including poor water quality and safety, contamination of water sources, scarcity of water sources, ageing infrastructure, maintenance of existing infrastructure, poor management of water utilities, decision-making challenges, inadequate funding, income gaps, inadequate sewage treatment systems and operational inefficiencies.

The initial literature survey in this study revealed that one of the major challenges faced by water utilities in transitional countries is ineffective decision-making in water asset management. This has resulted into many inherent issues like leakages in the pipe networks with the poor condition of the existing infrastructure, and high levels of non-revenue water (Mugisha & Berg, 2008; NWSC, 2009). According to Kingdom et al., (2006), most water utilities in transitional countries have NRW that exceeds 50%. There is also growing evidence which suggests that the integrity of drinking water and wastewater infrastructure is at risk. This is because there is no collaborative effort to improve the management of key assets such as pipelines, treatment plants, and other facilities coupled with lack of significant investment in maintaining, rehabilitating, and replacing these assets (Bhagwan, 2009).

Consequently, this study set out to develop a decision enhancement studio which would facilitate complex asset management decisions through providing services to enhance decision-making in the water utilities. It was envisaged that the decision enhancement studio for water asset management would provide services that would enable stakeholders come together to make effective decisions on water asset management as suggested by Keen & Sol (2008).

SUMMARY

In order to fulfil the main objective of this study which was to develop a DES-WAM studio to enhance decisions in the water utilities, this study adopted the inductive-hypothetic strategy. The explanation for employing the inductive-hypothetic research strategy was to ensure that the studio was shaped by the organisational context during development and use while combining practice and theory (Sol, 1982). The strategy was executed in five stages, namely initiation, abstraction, theory formulation, implementation, and evaluation (Gonzalez & Sol, 2012).

The initiation stage was concerned with identifying decisions that mattered most in water asset management. The initiation stage involved a pilot study to test the research instrument and gather information prior to a larger study. This was done to improve the quality and efficiency of the data collection methods and was conducted with sector managers at National Water and Sewerage Corporation (NWSC). Permission to carry out data collection was sought and granted in three water utilities; NWSC, Uganda, Rand Water, Johannesburg, South Africa; and Waterbedrijf, Groningen, the Netherlands.

The second stage focused on abstraction. In the abstraction stage, the key issues in water asset management and requirements for a DES-WAM were identified. At this stage, the research design, data collection methods and study respondents were identified (McAdam et al., 2011).

The theory formulation stage involved describing the service values that the studio would deliver to sector managers, the important activities to be performed and the resources that were required, including a preliminary implementation scope. In the theory formulation stage, the approach to the DES-WAM was introduced.

The fourth stage involved prototyping and implementation of the studio in the three water utilities of NWSC in Uganda, NCWSC in Nairobi, Kenya and KIWASCO in Kisumu, Kenya. In this study, 2 prototype iterations (1 paper-based prototype developed and the final computerized prototype) were made. Pre-tests of prototype were done at two

organizations and the findings were used to develop the final prototype. The studio was later implemented in the three water utilities.

The fifth stage focused on the evaluation of the DES-WAM in the three water utilities. During the evaluation stage, questionnaires were developed with questions and statements that were aimed at soliciting the respondents' appreciation of the DES-WAM with regard to usability and usefulness. The evaluation results revealed that the DES-WAM was usable. The study respondents in all the three water utilities noted that the studio was accessible; it provided insights on incidents displayed using markers and that the complaints suite provided visualization of incidents provided. The study further found that the studio supported navigation, provided insight into the level of consensus and supported knowledge sharing. The evaluation results also show that the studio provided guidelines for effective decision-making, supported expert facilitation and was easy to use. The evaluation results also found that there was perceived usefulness of the studio in enhancing decisions which lead to: reduction in non-revenue water, leakage reduction, increased response time, increased knowledge about the water pipe network systems, increased fire fighting capability, reduced property damage, reduced risk of contamination and more stabilized water pressure throughout the system. This is in line with maintenance management.

This study contributes to society and knowledge. To the society, the study provides a studio that will enhance asset management decisions in water utilities. The water utilities can use the studio to address the challenges of provision of water and sanitation to the communities. The stakeholders can possibly use the studio to work collaboratively to improve service delivery, increase response time to incidents, provision of information to handle maintenance issues promptly, and being able to prioritise investment planning for small-term and medium-term replacement/refurbishment decisions on infrastructure in water utilities.

The studio may also be used by the water utilities to improve operations by enhancing: management of assets for water utilities, decisions making, reducing NRW, reducing

leakages, reducing vandalism of assets and reducing property damage. Overall, using the studio may result into operational and tactical level decisions for the short to medium term period. It includes the maintenance and replacement decisions and scheduling / planning / prioritization. This is in line with maintenance management, which addresses both non-revenue water and infrastructure asset management.

Regarding knowledge, the study provides evidence that asset management decisions in water utilities can be enhanced by the use of a decision enhancement studio like DES-WAM. This is because it is useful and can be used by even the resource constrained water utilities in transitional countries since it is a low-cost system.

The key challenge to the study was getting hold of the respondents because of their busy schedules. As a result, this affected response rates, especially at NWSC where only three people participated in the evaluation. However, this was surmounted by rescheduling appointments with the respondents in order to fit in their schedules.

The other challenge facing the study was refusal by some water utilities and participants to divulge some information citing sensitivity and the associated dangers of information exposure on weaknesses and flaws in their asset management practices. This challenge was overcome by assuring the participants of confidentiality and re-affirming that the study findings could only be used for academic purposes.

This study has demonstrated that in order for small to medium water and sanitation utilities to improve water asset management decisions, there is need for a decision enhancement studio for water asset management. Consequently, this study provides a solution in form of the DES-WAM which is aimed at enhancing water asset management decisions. Empirical evidence in this study suggests that indeed the DES-WAM is a useful tool for enhancing asset management decisions.

The study respondents noted that the studio could be used to address the challenges to water asset management like non-revenue water, damage to assets, vandalism, reducing leakages and increasing response time. It was also established that the tool was usable

and it could therefore be used by decision-makers in the water utilities to enhance water asset management decisions. Basing on the positive results of usefulness and usability of the studio, the DES-WAM is effective in enhancing decisions for water asset management by supporting decisions that will result into maintenance management for the water utilities.

Further research may be carried out in the following areas:

Recommendation 1: Implementation and evaluation of the studio among water utilities in the developed countries in order to validate its usefulness and usability. This will allow for the generalization of the study findings.

Recommendation 2: Evaluation of the DES-WAM by users from small to medium water and sanitation utilities who were not exposed to the studio in other transitional regions as a way of ascertaining its usability and usefulness. This will enable comparison of their results with ours in order for us to generalize about the studio.

Recommendation 3: Use of bulk water suppliers as case studies and larger samples of respondents for purposes of generalizing findings and conclusions on the usability and usefulness of the DES-WAM.

Recommendation 4: Adaptation or expansion of the studio prototype to cater for: other non-revenue water causes; larger bulk water and sanitation utilities with more mature IT systems landscapes (including systems integration); broader and / or strategic longer-term infrastructure asset management decisions including more support for this by the studio. Alternatively, even emergency or disaster related water infrastructure decisions (such as a "war room" scenario) may require integration with a control system or systems (for example SCADA type of system).

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APPENDIX A

Exploratory study participants from 3 Water Utilities and their Management Levels

Participants from Rand Water, South Africa	Management Level
Asset Management Electrical	Tactical
Asset Planning GIS Manager	Operational
Asset Planning Manager	Tactical
Design Office Manager	Operational
Group Strategy-Researcher	Strategic
Maintenance System Manager	Operational
Manager IT Applications	Tactical
Senior Manager Assets	Strategic
Manager-Strategic Customer	Strategic
Water Quality Specialist	Strategic
Maintenance Planning Manager	Operational
Manager Technology Training	Tactical

Participants from Waterbedrijf Groningen, the Netherlands	Management Level
Head New Production Assets	Tactical
Project Leader New Production Assets	Tactical
Head Strategy and Research	Strategy
Asset Manager & Asset Officer	Strategy/tactical
Sector Manager Water Supply	Operations
Distribution Mechanic	Operations
Project Leader New Distribution Assets	Tactical
Maintenance Engineer	Tactical/operational
Manager International Cooperation	Tactical

Participants from National Water and Sewerage Corporation, Uganda	Management Level
Senior Software Developer	Tactical /Operational
Development & External Services Division	Operational
Senior Infrastructure Planner	Strategic/Tactical
Urban Pro Poor Manager	Operational
Chief Manager, Planning & Capital Development Division	Strategic
Maintenance Engineer, Gaba	Operational
Manager Quality Control	Tactical/Operational
Senior Manager Systems Supervision	Strategic/Tactical/Operational
Principle engineer Infrastructure Planning &	Tactical

Participants from National Water and Sewerage Corporation, Uganda	**Management Level**
Development (Project Management)	
Network Planning Manager-Kampala Water	Operational
Principle Engineer-Gaba 3	Operational
Senior Manager Operations	Strategic/Tactical/Operational
Manager Projects- Monitoring and Evaluation-	Strategic/Tactical/Operational
Senior Manager IT	Tactical
Human Resources	Tactical/Operational

APPENDIX B

Research into the Decision Enhancement Studio for Water Asset Management

Dear respondent, my name is Proscovia Mayanja Katumba. I am an Assistant Lecturer at Makerere University and currently working on a research study at the University of Groningen, in the Netherlands, for a study leading to the award of the degree of Doctor of Philosophy in Information Systems Management. I am collaborating with National Water & Sewerage Corporation (NWSC) Uganda on enhancing decision-making in water asset management. This is in the initial phase of an exploratory exercise looking at the research area and problem definition 'Decision enhancement services for water asset management'.

This case study research looks at several scenarios to benchmark with similar organizations worldwide in order to develop asset management systems that are best of breed. The study seeks to understand the experiences and specific challenges of decision-making in Asset Management of in four water utilities, namely NWSC-Uganda, Rand Water-South Africa, and Waterbedrijf Groningen- the Netherlands. Within this PhD project, the promoter is Prof. Dr. Henk G. Sol of the University of Groningen, Faculty of Economics and Business, The Netherlands; and research supervision is done by Prof. Dr. Jude Lubega, Uganda Technology and Management University at Kampala, Uganda.

The study intends to pave way for a replicable and applicable new knowledge in enhanced decision services in water asset management. I would like to request for your time in participating in a structured interview for an exploratory study. I would be happy to send you a copy of my final report, upon request. Your participation will be very much appreciated.

---

1. What water assets for maintenance management are vital in water service delivery by the utility but are not owned by the same?
2. Which water production maintenance systems are critical to sustained performance?
3. What is the likelihood of asset failure in the water utility?

Asset	Low	Medium	High
Buildings and Property			
Civil Structures			
Pipelines and Servitudes			
Electrical Equipment			

Asset	Low	Medium	High
Mechanical Equipment			
Process Plants			
Automation Equipment			

4. What causes asset maintenance failure?

5. What are the consequences of asset maintenance failure to service levels?

6. What asset maintenance practices are employed at the utility?

Asset	Management Practices
Buildings and Property	
Civil Structures	
Pipelines and Servitudes	
Electrical Equipment	
Mechanical Equipment	
Process Plants	
Automation Equipment	

7. Evaluate the information systems at the water utility in terms of strengths, weaknesses, risk areas and improvement opportunities for effective water asset maintenance.

Name of system in use	Strength	Weaknesses	Risk areas	Needed improvements

8. What do you think is not handled well in water asset management (maintenance management)?

9. Propose ways of how you think this maintenance management can be improved.

10. What decisions in maintenance management need to be made? (Decisions that matter)

11. Identify existing maintenance management services

12. Identify existing guidelines for maintenance management in the water utility

13. Identify existing tools for maintenance management in the utility

14. What are the current maintenance management decision-making practices in this water utility?

Assets	Decision Making Practices
Buildings and Property Civil Structures	
Pipelines and Servitudes	
Electrical Equipment	
Mechanical Equipment	
Process Plants	
Automation Equipment	

15. What are some of the maintenance management challenges in the Water Utility?

16. What maintenance management decisions in water utilities should be enhanced? Alternatively, what decisions in maintenance management need to be made? (Decisions that matter)

17. What should be the requirements for a water asset management (maintenance management) decision enhancement environment/solution?

Thank You for Your Time

APPENDIX C

A QUESTIONNAIRE TO ASSESS THE DES-WAM

Introduction

The DES-WAM studio is an environment packaged in technology suites, recipes and services that can be used to focus and structure a team's decision-making while reducing cognitive costs of communication and information access and minimizing distraction among teams working collaboratively towards a goal. In about 10 minutes, please fill out this questionnaire to assess the usability and usefulness of the DES-WAM studio prototype.

Usability

Usability is the degree to which the collaboration session supports you in performing generation of asset maintenance alternatives. From your experience in the collaboration session, please answer the following questions.

i. Are you able to gain access to the studio using the credentials provided?

Yes ☐ No ☐

ii. Does the dashboard provide insight on incidents displayed using markers?

Yes ☐ No ☐

iii. Does the complaints suite provide visualization on incidents reported?

Yes ☐ No ☐

iv. Does the studio support navigation?

Yes ☐ No ☐

v. Does the studio provide insight in level of consensus?

Yes ☐ No ☐

vi. Does the studio support knowledge sharing?

Yes ☐ No ☐

vii. Does the studio provide guidelines to effective decision-making?

Yes ☐ No ☐

viii. Does the studio support expert facilitation?

Yes ☐ No ☐

ix. Is it difficult to use the studio?

Yes ☐ No ☐

x. a. Rate how easy it is to learn the collaboration tool? (1=very hard, 2=hard, 3= neither hard nor easy, 4= easy, 5= very easy)

……

b. List any challenges you may have faced?

……

……

c. Suggest ways of improving it.

……

……

xi. a. Rate how easy it is to use the collaboration tool? (1=very hard, 2=hard, 3= neither hard nor easy, 4= easy, 5= very easy)

……

b. List any challenges you may have faced

……
……
……

c. Suggest ways of improving it.

……
……

xii. Rate how easy it is to understand the user interface. (1=very hard, 2=hard, 3= neither hard nor easy, 4= easy, 5= very easy)

……

b. List any challenges you may have faced.

……

……

c. Suggest ways of improving it.

……

……

xiii. The studio offers repeatable processes that provide structure and can be run by stakeholders in a collaborative session (1= strongly disagree, 2= disagree, 3= not sure, 4= agree, 5= strongly agree)…….

xiv. The studio enhances collective participation of all stakeholders without fear of victimization on divergent brainstorming (1= strongly disagree, 2= disagree, 3= not sure, 4= agree, 5= strongly agree)…….

xv. The studio facilitates a converging process where information is used (1= strongly disagree, 2= disagree, 3= not sure, 4= agree, 5= strongly agree)
……..

xvi. DES-WAM offers facilitation scripts to create a predictable pattern of collaboration on decision making. (1= strongly disagree, 2= disagree, 3= not sure, 4= agree, 5= strongly agree)…….

xvii. The DES-WAM provides guidelines as well as scripts with facilitation to achieve the meeting objectives. (1= strongly disagree, 2= disagree, 3= not sure, 4= agree, 5= strongly agree)…….

xviii. The DES-WAM provides a knowledge base and training in asset management creating awareness on the subject given. (1= strongly disagree, 2= disagree, 3= not sure, 4= agree, 5= strongly agree)……

xix. How many asset maintenance alternatives were generated by the studio?

☐ Below 5 ☐ 5-10 ☐ Above 10

Usefulness

Usefulness refers to the ability of the collaboration meeting (activities carried out today) to provide support to a particular level to work together to jointly generate asset maintenance alternatives. From your experience in the collaboration session, please answer the following questions.

i. Does the studio enhance decisions that lead to reduction in non-revenue water?

☐ Yes ☐ No

ii. Does the studio enhance decisions that lead to water leakage reduction?

☐ Yes ☐ No

iii. Does the studio enhance decisions that lead to increased response time to asset failures?

☐ Yes ☐ No

iv. Does the studio enhance decisions that lead to increased knowledge about the water pipe network systems?

☐ Yes ☐ No

v. Does the studio enhance decisions that lead to increased fire fighting capability by the water utility?

☐ Yes ☐ No

vi. Does the studio enhance decisions that lead to reduced property damage?

☐ Yes ☐ No

vii. Does the studio enhance decisions that lead to reduced risk of water contamination?

☐ Yes ☐ No

viii. Does the studio enhance decisions that lead to more stabilized water pressure throughout the system?

☐ Yes ☐ No

ix. Rate the usefulness of the collaboration meeting for the generation of asset maintenance alternatives.

☐ Very Good ☐ Good ☐ Fairly Good ☐ Poor ☐ Very Poor

x. Rate the suitability of the collaboration meeting for the generation of asset maintenance alternatives

☐ Very Good ☐ Good ☐ Fairly Good ☐ Poor ☐ Very Poor

xi. How would you rate the suggested asset maintenance alternatives.

☐ Very Good ☐ Good ☐ Fairly Good ☐ Poor ☐ Very Poor

xii. Please provide additional comments, if any.

……

……

……

Thank You For Your Time

APPENDIX D

DES-WAM Studio Evaluation-Qualitative Questionnaire Results

NWSC-KAMPALA		
OI10	What are the main obstacles to achieving Asset Management? × The field personnel who attend to most complaints do not have full access to the Internet/network so can't use system fully × The current major obstacle is the policy × After the policy, we then need to develop an asset register and value our assets to determine the current values. The rest can then follow. × Financing the exercise	Experts
USA i(b)	List any challenges you may have faced in learning the collaboration process × Joining the discussion but this was due to a system bug × Accessibility of the site – premise dependent or network dependent	Experts
USA i(c)	Suggest ways of improving it (learning) × Providing for offline component × Addressing all bugs	Experts
USA ii (b)	List any challenges you may have faced in the use of the collaboration tool × How about if one of the discussants want to invite a friend?	Experts
USA ii (c)	Suggest ways of improving it (use) × Provide an option to allow the discussant to suggest who to invite to the administrator × SMS alerts used in the prototype would be suitable since most of the field staff are not IT literate	Experts

KIWASCO - KENYA		
OI10	What are the main obstacles to achieving AM?	
	× The company lacks clearly stated and documented AM policy	Operations
	× Conflicting ideas/interests	Tactical
	× Imbalance in skilled manpower	Tactical
	× Interest/motivation	Tactical
	× Lack of detailed information on existing assets managed by the company	Tactical
	× Institutional existing framework which puts the role of asset ownership in a different institution	Tactical
	× Funding /Financing	Tactical
	× Lack of an enabling environment/lack of political will	Tactical
	× Confused legal operating atmosphere	Tactical
	× Lack of top management commitment	Strategic
	× Lack of proper tracking system	Strategic
	× Coordination of agencies both government and non-	Strategic

KIWASCO - KENYA		
	government	Strategic
	× Lack of AM committee to deal with the policy issues	Strategic
	× Lack of sensitisation of all personnel at all sites	Strategic
	× Cost	Strategic
	× Poor planning	Strategic
	× Fear of taking risk	Strategic
	× Policy not well communicated to staff	Strategic
	× Poor planning	Strategic
	× Lack of involvement of all staff	Strategic
	× Lack of a strategy communication plan within the company	Strategic
	× The organization lacks a clearly stated and communicated strategy to support the change management required for AM	Operations
	× Lack of commitment and urgency to develop AM systems	Operations
	× Will in top management is lacking	Operations
	× Commitment from top management and communication of the AM to the entire organization	Operations
	× Having the necessary policy to initiate the process	Operations
	× The assets have not been mapped to completion	Operations
	× Communication	Operations
	× Political instability within the region	Tactical
	× Other related service providers developing who actually to interface with the infrastructure	Tactical
	× Communication, genuine commitment of management to AM	
USA i(b)	List any challenges you may have faced in learning the collaboration process	Tactical
	× Login – sometimes system was down with no Internet access	Tactical
	× Getting real time feedback from the programmer in case of problems with the prototype	Tactical
	× Requires one to be technology savvy, one which may hamper the uptake because many utility staff are not that computer literate	Tactical
	× Internet connection	Tactical
	× Lack of enough computers to do it at a personal level	Strategic
	× Accessing the studio with no Internet is difficult	Strategic
	× Accessing the Internet	Strategic
	× Network availability	Strategic
	× Accessing the site at first to join the session with no Internet	Strategic
	× It is dependent on the competence of the administrator	Strategic
	× Internet connections are weak	Strategic
	× Access control makes it dependent on the administrator's speed and availability	Strategic
	× Navigation requires keenness all the time	Operations
	× Internet connection	Operations
	× The complaint forum would be challenging to select all the complaints	Operations
	× Help page was inaccessible	Operations
	× Must be well trained	Tactical

KIWASCO - KENYA		
USA i (c)	Suggest ways of improving it (learning)	
	× Organize for the training and awareness sessions	Tactical
	× Improve Internet connection	Tactical
	× Provide more computers for staff	Tactical
	× Provide modem for Internet access	Strategic
	× Increasing the Internet efficiency	Strategic
	× Strong Internet availability is required	Strategic
	× Improved Internet infrastructure	Strategic
	× Invest in faster Internet connections	Strategic
	× Create time lags between administrator and users	Operations
	× Roll-down buttons on listed options to select from	Operations
	× Usability should cover every aspect of industrial set up and not just known operational parameters	Operations
	× More experience and time	Operations
	× Make the help page accessible	Operations
	× Awareness must be done to staff	Operations
	× Continuous use of the tool in order to improve in decision process	Operations
USA ii (b)	List any challenges you may have faced in the use of the collaboration tool	Tactical
	× Lack of user manual or help page	Strategic
	× Weak Internet connection	Strategic
	× Administrator was too fast and systems take time to become operational	Strategic
	× Navigation requires a lot of keenness	Strategic
	× Selecting the icons sequentially is a challenge	
USA ii (c)	Suggest ways of improving it (use)	
	× Please make help page or manual be part of the software	Tactical
	× Improve connectivity to Internet	Strategic
	× More time is required to assist the attendees understand the process	Strategic
	× More coaching is required	Strategic
	× More time needs to be allocated due to the Internet disruptions	Strategic

NCWSC-KENYA		
OI10	What are the main obstacles to achieving AM?	
	× The organizational structure does not have AM unit	Operations
	× Resources to operationalize AM	Operations
	× The policy is non-existent or if it is in place, it is not well communicated	Operations
	× Pre-planned target of coordinated management of assets that can be reviewed occasionally	Tactical
	× Standardized modes of managing assets before upgrade/declared defunct	Tactical
	× Priorities are different. The more urgent and pressing issues are addressed first then others follow. This is a time bomb.	Operations
	× Management's commitment	Tactical

NCWSC-KENYA		
	× Capacity (HR) gap × Lack of updated asset register × Existence of multiple assets registers & ownership by different organisation × Water Assets operated by the NCWSC belong to the Water Services Board (AWSB) × The company has not yet initiated the process × The Internet connectivity is a challenge × Full internalization of the AM system and lack of information collecting mechanism × The infrastructure (network and meter locations) not mapped at all and where mapped, it is inaccurate × Lack of necessary tools to do so × Management not ready to undertake projects whose value is not short term. They are always thinking of revenue. × AM has never been appreciated as a need in the company × The company is first trying to get data on its infrastructure in Nairobi	Tactical Operations Operations Operations Tactical Strategic Strategic Strategic Operations Operations Operations Tactical
USA i(b)	List any challenges you may have faced in learning the collaboration process × The Internet speed, some models not functional and the server not responding × Anonymity × Internet connectivity × Limited time (give it a month) × More time required × Network connectivity	Operations Operations Tactical Tactical Strategic Tactical
USA i(c)	Suggest ways of improving it (learning) × Training and user manual × Use of better ways for connectivity to the Internet × Provide option for identifying users while online × Allocate more time for such sessions × Provide all applications for purposes of processing say for a period of one month × Need more time to be able to evaluate × Accountability of decisions arrived at after deliberations × Improve the Internet connectivity	Tactical Operations Operations Tactical Tactical Strategic Tactical Tactical
USA ii (b)	List any challenges you may have faced in the use of the collaboration tool × One needs to be keen and click on the correct/right icon	Operations
USA ii (c)	Suggest ways of improving it (use) × Train users (Tutorials) × Train on basic IT skills needed × More testing time to have a feel and sharpen the skills is required	Tactical Operations Operations

SAMENVATTING

De aanleiding voor deze studie werd gevormd door verslagen over de uitdagingen op het gebied van waterassetbeheer in transitielanden (Ardakanian & Martin-Bordes, 2007). De studie begon met een onderzoek naar wat voor waterbedrijven de belangrijkste uitdagingen waren wat betreft schoonwatervoorziening en waterassetbeheer. Uit het eerste onderzoek bleek dat waterbedrijven te maken hadden met verschillende problemen, waaronder slechte waterkwaliteit en -veiligheid, verontreiniging van waterbronnen, schaarste aan waterbronnen, een verouderende infrastructuur, onderhoud van de bestaande infrastructuur, slecht beheer bij waterbedrijven, besluitvormingsproblemen, onvoldoende financiering, inkomensverschillen, slechte rioolwaterzuiveringsinstallaties en operationele inefficiëntie.

Uit het eerste literatuuronderzoek bleek dat een van de grootste problemen voor waterbedrijven in transitielanden de ineffectieve besluitvorming in het waterassetbeheer is. Dit heeft veel problemen opgeleverd, zoals lekkages in de pijpleidingnetwerken door de slechte staat van de huidige infrastructuur, en grote hoeveelheden niet-afgerekend water (*Non-Revenue Water*, NRW) (Mugisha & Berg, 2008; National Water and Sewerage Corporation (NWSC), 2009). Volgens Kingdom et al. (2006) hebben de meeste waterbedrijven in transitielanden een NRW-percentage van meer dan 50%. Ook is er steeds meer bewijs waaruit zou blijken dat de integriteit van de drinkwater- en afvalwaterinfrastructuur gevaar loopt. Dit komt doordat er niet wordt samengewerkt om het beheer van de belangrijkste assets te verbeteren, zoals pijpleidingen, zuiveringsinstallaties en andere voorzieningen. Daarnaast wordt er onvoldoende geïnvesteerd om deze assets te onderhouden, herstellen en vervangen (Bhagwan, 2009).

In het kader van deze studie werd daarom een decision enhancement studio ontwikkeld, die door middel van dienstverlening complexe assetbeheerbeslissingen mogelijk moet maken om zo de besluitvorming bij waterbedrijven te bevorderen. Deze decision enhancement studio voor waterassetbeheer zou diensten moeten verlenen waarmee belanghebbenden samen effectieve beslissingen over waterassetbeheer kunnen nemen, zoals voorgesteld door Keen & Sol (2008).

Om het belangrijkste doel van deze studie te realiseren, namelijk het ontwikkelen van een DES-WAM-studio om besluitvorming bij waterbedrijven te bevorderen, is gebruikgemaakt van een inductief-hypothetische strategie. Deze onderzoeksstrategie moest ervoor zorgen dat de studio tijdens zijn ontwikkeling en gebruik door de organisationele context zou worden gevormd en dat praktijk en theorie hierbij zouden worden gecombineerd (Sol, 1982). De strategie werd toegepast in vijf fases, nl. initiatie, abstractie, theorieformulering, implementatie en evaluatie (Gonzalez & Sol, 2012).

In de initiatiefase werden de beslissingen geïdentificeerd die er in het waterassetbeheer het meest toe doen. De initiatiefase omvatte een pilotstudy om voorafgaand aan een grotere studie het onderzoeksinstrument te testen en informatie te verzamelen. Doel van de pilotstudy was om de kwaliteit en efficiëntie van de dataverzamelmethodes te verbeteren. De pilot werd uitgevoerd met sectormanagers van de NWSC in Oeganda. Drie waterbedrijven gaven toestemming om data te verzamelen: de NWSC in Oeganda; Rand Water in Johannesburg, Zuid-Afrika; en het Waterbedrijf in Groningen.

De tweede fase was gericht op abstractie. In de abstractiefase werden de belangrijkste problemen in het waterassetbeheer en de vereisten voor een DES-WAM vastgesteld. Ook werden in dit stadium het onderzoeksontwerp, de dataverzamelmethodes en de respondenten vastgesteld (McAdam et al., 2011).

In de theorieformuleringsfase werden de servicewaarden van de studio voor de sectormanagers beschreven, de belangrijke uit te voeren activiteiten en de hiervoor vereiste middelen, en een voorlopig implementatiegebied. In deze fase werd ook de benadering van de DES-WAM geïntroduceerd.

De vierde fase betrof prototyping en implementatie van de studio in drie waterbedrijven: NWSC in Oeganda; NCWSC in Nairobi, Kenia; en KIWASCO in Kisumu, Kenia. In deze studie werden twee prototype-iteraties gemaakt (een op papier ontwikkeld prototype en het uiteindelijke gecomputeriseerde prototype). Bij twee organisaties werden pre-tests

met het prototype uitgevoerd; de bevindingen werden gebruikt om het uiteindelijke prototype te ontwikkelen. Later werd de studio geïmplementeerd bij de drie waterbedrijven.

De vijfde fase richtte zich op de evaluatie van de DES-WAM in de drie waterbedrijven. Tijdens de evaluatiefase werden vragenlijsten ontwikkeld met vragen en stellingen over de bruikbaarheid en het nut van de DES-WAM. Uit de evaluatieresultaten bleek dat de DES-WAM bruikbaar was. De respondenten bij alle drie de waterbedrijven merkten op dat de studio toegankelijk was; deze bood aan de hand van markers inzicht in incidenten, en ook zorgde de klachtensuite voor een visualisatie van de incidenten. Voorts bleek uit de resultaten dat de studio navigatie en kennisuitwisseling ondersteunde en inzicht gaf in het consensusniveau. Uit de evaluatieresultaten bleek ook dat de studio richtlijnen voor effectieve besluitvorming bood, deskundigen kon faciliteren en gebruiksvriendelijk was. Tevens toonden de evaluatieresultaten aan dat de studio beslissingen bevordert die leiden tot minder niet-afgerekend water, minder lekkages, een kortere reactietijd, meer kennis van de pijpleidingnetwerken, betere brandbestrijding, minder zaakschade, minder risico op verontreiniging en een stabielere waterdruk in het hele systeem. Dit is in lijn met het onderhoudsbeheer.

Deze studie levert een bijdrage aan zowel de samenleving als de wetenschap. Het onderzoek levert een bijdrage aan de samenleving door middel van een studio die assetbeheerbeslissingen bij waterbedrijven bevordert. Waterbedrijven kunnen de studio gebruiken om problemen in hun water- en rioleringsvoorziening aan te pakken. Belanghebbenden kunnen de studio gebruiken om samen hun dienstverlening te verbeteren, hun reactietijd op incidenten te verkorten, informatie te geven zodat onderhoudsproblemen tijdig kunnen worden opgelost, en investeringsplannen voor vervanging en verbouwing van infrastructuur op de korte en middellange termijn te kunnen prioriteren.

Waterbedrijven kunnen de studio ook gebruiken om bedrijfsprocessen te verbeteren aan de hand van een beter assetbeheer, betere besluitvorming, minder NRW, minder

lekkages, minder vernieling van assets en minder zaakschade. Kortom, gebruik van de studio kan leiden tot beslissingen op operationeel en tactisch niveau voor de korte tot middellange termijn, bijvoorbeeld inzake onderhoud en vervanging, en planning en prioritering. Dit is in lijn met het onderhoudsbeheer, dat zowel niet-afgerekend water als infrastructuurassetbeheer betreft.

Daarnaast levert het onderzoek een bijdrage aan de wetenschap omdat het aantoont dat assetbeheerbeslissingen bij waterbedrijven kunnen worden bevorderd door een decision enhancement studio als DES-WAM te gebruiken. De studio is nuttig en kan ook worden gebruikt door waterbedrijven in transitielanden met beperkte middelen, omdat het een voordelig systeem is.

De grootste uitdaging in het onderzoek was het te pakken krijgen van de respondenten vanwege hun drukke schema's. Dit heeft de responsieniveaus negatief beïnvloed, met name bij NWSC waar slechts drie respondenten aan de evaluatie deelnamen. Dit werd echter opgelost door afspraken met de respondenten te verschuiven zodat deze in hun schema pasten.

De andere uitdaging in het onderzoek was dat sommige waterbedrijven en deelnemers weigerden om informatie vrij te geven omdat deze gevoelig zou zijn en wellicht tekortkomingen in hun assetbeheerpraktijken bloot zou leggen. Dit werd opgelost door geheimhouding te garanderen en nog eens te benadrukken dat de onderzoeksresultaten alleen voor academische doeleinden worden gebruikt.

Uit deze studie blijkt dat een decision enhancement studio voor waterassetbeheer noodzakelijk is om besluitvorming bij kleine tot middelgrote water- en rioleringsbedrijven te verbeteren. Dit onderzoek biedt een oplossing in de vorm van de DES-WAM, die als doel heeft waterassetbeheerbeslissingen te bevorderen. Empirisch bewijs toont aan dat de DES-WAM inderdaad een nuttig instrument is om assetbeheerbeslissingen te bevorderen.

De respondenten merkten op dat de studio gebruikt kan worden om problemen als niet-afgerekend water, assetschade, vandalisme, lekkages en responstijd het hoofd te bieden. Ook werd vastgesteld dat het instrument bruikbaar is en kan worden gebruikt door besluitvormers bij waterbedrijven om waterassetbeheerbeslissingen te bevorderen. Positieve resultaten wat betreft het nut en de bruikbaarheid van de studio tonen aan dat de DES-WAM effectief is bij het bevorderen van waterassetbeheerbeslissingen; deze studio ondersteunt beslissingen die leiden tot onderhoudsbeheer bij de waterbedrijven.

Verder onderzoek kan worden uitgevoerd op onderstaande gebieden:

Aanbeveling 1: Implementatie en evaluatie van de studio bij waterbedrijven in ontwikkelde landen teneinde zijn nut en bruikbaarheid te valideren. Dit maakt het mogelijk de onderzoeksbevindingen te generaliseren.

Aanbeveling 2: Evaluatie van de DES-WAM door gebruikers uit kleine tot middelgrote water- en rioleringsbedrijven die niet zijn blootgesteld aan de studio in andere transitieregio's, om zo zijn bruikbaarheid en nut na te gaan. Dit maakt het mogelijk om hun resultaten met de onze te vergelijken en over de studio te generaliseren.

Aanbeveling 3: Gebruik van bulkwaterleveranciers als casestudy's en grotere steekproeven respondenten om bevindingen en conclusies over bruikbaarheid en nut van de DES-WAM te generaliseren.

Aanbeveling 4: Aanpassing of uitbreiding van het studioprototype zodat dit rekening houdt met: andere oorzaken van niet-afgerekend water; grotere bulkwater- en rioleringsbedrijven met volwassener IT-systeemlandschappen (waaronder systeemintegratie); bredere en/of strategischer langetermijnbesluitvorming op het vlak van infrastructuurassetbeheer, die beter door de studio wordt ondersteund. Daarnaast moeten mogelijk waterinfrastructuurbeslissingen die verband houden met een noodgeval of ramp (zoals een *war room*-scenario) worden

geïntegreerd met een controlesysteem of -systemen (bijvoorbeeld een SCADA-systeem).

CURRICULUM VITAE

Proscovia Mayanja Katumba was born on 2nd August 1967 at Uasin Gishu, Kenya. She pursued her Bachelor's degree in Business Administration majoring in Office and Information Management (BBA-OIM) at Makerere University, Uganda and completed in 2000. In her final year project during her BBA-OIM degree which was titled *"Mobile Telephony: the case of MTN and Celtel, Uganda"*, she sought to investigate techniques employed by MTN to become the strongest brand in Ugandan telecoms. She graduated with a Second Class Honour's degree, and was retained in the Faculty of Commerce, Makerere University as a Teaching Assistant. She embarked on her Masters in Information Systems Management at Makerere University in collaboration with London South Bank University (LSBU), United Kingdom. Her Masters Dissertation was titled *"Transformation of Local Government using Customer Profiling: The case of Islington, Lambeth, Hammersmith and Fulham, United Kingdom."* She was awarded a Master of Science with distinction in Information Systems Management at London South Bank University in 2007. Her thesis was published as a monograph.

Prior to pursuing her doctorate, she worked both in industry and in academia. In industry, Proscovia has worked with a number of organizations public and private, local and regional including Tanzania Communications Regulatory Authority, Ministry of Natural Resources, Lesotho; Ministry of Finance, Tanzania; and Bank of Uganda as a corporate management consultant. In academia, she led a research team of seven researchers to the Western Region of Uganda during the Global Entrepreneurship Monitor (GEM) Uganda 2009 Adult Population Survey under Makerere University Business School (MUBS). Proscovia has been trained by the International Labour Organization for a trainer of trainers in Entrepreneurship and eLearning and also took part in an eLearning Africa Conference during the month of May 2014; she then trained several youth on the eLearning platform.

She works with Makerere University as an assistant lecturer in the School of Business. She conducted her PhD research at the Faculty of Business and Economics, the University of Groningen, the Netherlands. Her exploratory studies were both in sub-Saharan Africa and Europe including Rand Water, Johannesburg South Africa, Waterbedrijf Groningen, the Netherlands, National Water & Sewerage Corporation, Uganda. She also examined other cases in sub-Saharan Africa during an asset management research workshop she organized during the month of January 2013 at the Rand Water Academy in Vereeniging, South Africa.

A DECISION ENHANCEMENT STUDIO FOR WATER ASSET MANAGEMENT

The Decision Enhancement Studio for Water Asset Management (DES-WAM) was instantiated in Nairobi City Water and Sewerage Company, Kenya (NCWSC), Kisumu Water and Sanitation Company, Kenya (KIWASCO) and National Water and Sewerage Corporation, Uganda (NWSC) in the area of decision enhancement and water asset management, particularly maintenance management.

Her research interests are in the fields of business, management, information systems, asset management, effective decision-making and design science.